

CHAPTER - 4 EXCAVATION AND EARTHWORK And CHAPTER - 21 SPECIAL ITEMS OF EARTH/MASONRY DAM AND CANALS

4.1 REFERENCES:-

IS : 2720 (Pt. II) - 1973	:	Determination of Water content (second revision)
IS : 2720 (Pt. XIV)- 1983	:	Determination of Density index (relative density) of cohesionless soils (first revision)
IS : 8237 - 1985	:	Code of practice for protection of slope for reservoir embankment (first revision)
IS : 8826 - 1978	:	Guide lines for design of large Earth and Rockfill dams
IS : 9429 - 1980	:	Code of practice for drainage system for Earth and rockfill dams
IS: 9556- 1980	:	Code of practice for design and construction of Diaphragm walls.
IS : 12200 - 1987	:	Code of practice for provision of Water stops at transverse contraction joints in masonry and concrete dams
	:	Specification for Irrigation projects in M. P. (1980)
	:	USR of Irrigation Works in M. P. & C.G. in force from 01.08.1984/ 01.4.1991/ 01.4.1998/ 01.12.2003
	:	Bombay PWD Specifications
	:	Specifications for Tawa Project.
	:	Specifications for Kolar Project
	:	CWC Specifications for masonry & earth dam of Rajghat Dam Project

4.2 TERMINOLOGY:-

Anchorage - Anchorage is a structure used to carry the lateral thrust of a wall. Ties to a series of concrete blocks or a continuous RCC beam, vertical or battered piles, inclined rock or soil anchors are generally used for this purpose.

Bentonite - A clay formed by alteration of volcanic ash and rich in montmorillonite clay mineral. Bentonite has exchangeable ions on the surface of particles. It swells in the presence of water and its suspensions are thixotropic.

Borrow area - The source of construction material required for earth and rockfill dam.

Casing - All zones other than the core in a zoned earth dam; also called shall or shoulder.

Core - A zone of impervious earth within zoned earth or rockfill dam.

Cut-off - A barrier to reduce seepage of water through foundation and abutments

(A) **Full cut - off** - A Cut - off taken to an impervious stratum.

Positive Cut - off - A full cut- off in the form of an open excavated trench and back filled with compacted impervious material.

NOTE - Full cut- offs also provided in the form of sheet piles, plastic diaphragm, concrete diaphragm, grouted cutoff, cutoff wall, etc.

(B) **Partial Cut - off** - A Cut - off which does not go down to impervious stratum.

Diaphragm wall - A wall constructed in situ by special trenching machines to act as cut - off wall or serve as a structural member. The standard widths range 100-800 mm for cut - off wall, 450 to 1200 mm for structural member.

Guide wall - walls of shallow depth built on both sides of the centre line of a diaphragm wall to guide the rabbing or boring tool for trench making in order to prevent collapse or trench panels and contain bentonite slurry.

Horizontal filter - A layer of uniform or graded pervious materials placed horizontally.

Impervious blanket - An upstream impervious soil layer laid over a relatively pervious stratum and connected to the core.

Inclined or vertical filter - A layer of uniform or graded pervious materials, placed inclined or vertical.

Inner longitudinal drain - A trench filled with filter material and laid along the downstream toe of the core of dam to collect seepage from core of the dam.

Inner cross drain - A trench filled with filter material to collect seepage from inner longitudinal drain and carry it to toe drain.

Panel - Unit trench/ wall excavated or cast at a time.

Primary Panel - Panels made along the main axis of the wall in the first series; and leaving suitable gaps for other (secondary) panels. Primary panels are usually cast with two stop and pipes for inter locking with the secondary panels.

Secondary Panel - Panels made along the main axis of the wall inter locked with the panels to form an effective and reasonably leak proof joint resulting in a continuous diaphragm wall.

Riprap - It is the protection to the embankment material against erosion due to wave action, velocity of flow, rain wash, wind action etc., provided by placing a protection layer of rock fragments or manufactured materials. Riprap may be placed on slope either by hand or it may be simply dumped.

(i) **Hand placed Riprap** - it consists of natural stones quarried, laid flat or laid with projection, boulders or specially manufactured, material like cement concrete blocks and soil cement blocks, carefully placed by hand in a more or less definite pattern with a minimum amount of voids, its top surface reasonably uniform and free of loose stones or alternatively panel wise concrete slabs or precast concrete interlocking type blocks.

(ii) **Dumped Riprap** - It consist of boulders or blasted rock reasonably free from quarry fines and dumped in place by mechanical means.

Rock toe - A zone of free draining material provided at the toe of the dam.

Toe drain - A trench with filter material laid along the downstream toe of an earth or rockfill dam to collect seepage from horizontal filter or inner cross drain and take it to natural drain.

Trenching - Excavation for a panel carried out in situ. Use of drilling mud may be necessary to prevent collapse of sides.

Turfing - it is a cover of grass grown over an area to prevent erosion of soil particles by rain wash

Wale - This is a horizontal member fixed to the wall. Its function is to transfer the horizontal thrust of the wall to the tie rods / struts.

4.3 GENERAL SPECIFICATION:

4.3.1 Bench Marks:

4.3.1.1 Before starting any work, a permanent bench mark, reference line and check profiles at convenient positions approved by the Engineer - in - charge shall be erected. The Benchmarks shall be as per Type Design 6 and 8 of Department. The words "B.M" with R. L. shall be conspicuously carved and painted on the benchmark. The reference line shall comprise of a base line properly dog belled on the ground with number of masonry pillar. The check profiles shall be of such materials and shall be located at such places as to ensure execution of all slopes; steps and excavation to the profile or profiles indicated in the approved drawings or as directed by the Engineer - in - charge.

4.3.1.2. The Sub - Divisional Officer on behalf of the Engineer - in - charge shall himself lay out all important levels, all control points with respect to this bench mark and reference line and correlate all levels and locations with this bench mark and the reference line. Important levels shall be checked by the Executive Engineer. All assistance shall be given for the same by the agency executing the work.

In the case of spread out works, several bench marks, reference lines and check profiles may be necessary and shall be constructed as directed by the Engineer - in - charge.

4.3.1.3. Except the mathematical and surveying instrument which shall be provided by the department all materials and labour for setting out works including construction of bench marks, reference lines, check profiles and survey required for setting out works as may be required at the various stages of the construction works shall be supplied or made by the agency executing the work.

4.3.2. Cross Section

4.3.2.1. Immediately prior to the beginning of the work, cross - section of the existing ground level at suitable intervals, normal to the axis of the dam., canal alignment and other channels, sluice waste weir or other masonry structures , etc., shall be taken over the base and seating of the dam ,channels or other structures, etc. for sufficient distance outside the limits. Levels on this cross section shall be taken at suitable interval not exceeding 6 m or as directed by the Engineer - in- charge.

4.3.2.2. These cross - sections shall be taken and plotted in ink by the Departmental agency. These cross sections shall form the basis of all future measurements and payments on the area.

4.4 CLASSIFICATION OF STRATA:

4.4.1 Soft or Ordinary Soil - Generally any soil which yields to the ordinary application of pick and shovel or to spade, rake or other digging implement, such as vegetable or organic soil, turf, gravel, sand, silt, loam, clay pear etc.

4.4.2. Hard Soil - Includes all materials which can be removed with shovel or spade after loosening with pick axe such as clay soil mixed with lime kanker, black cotton soil for earthen bond, soft moorum etc.

4.4.3. Hard Moorum and Moorum mixed with boulders - Generally any material which required the close application or picks, jumpers or scarifies to loosen such as hard and compact moorum and soft shale. Moorum or soil mixed with small boulder not exceeding 25 % in quantity and each less than 0.014 cum (300 mm dia) but more than 0.004 cum in size.

Note - Boulder is rock fragment usually rounded by weathering, disintegration or abrasion by water or ice, found lying loose on the surface or embedded in river bed, soil talus, slope wash and terrace material of dissimilar origin.

4.4.4. Disintegrated Rock - Includes such strata which requires the close application of crow bars, picks, grating tools, scarifiers in suitable combination for its excavation such as soft laterite, soft conglomerate, hard shale, soft copra, hard and compact moorum mixed with small boulders exceeding 25% in quantity but each not exceeding 0.014 cubic metre in size.

4.4.5. Soft Rock - Soft rock comprises of the following: -

(i) Boulders (not greater than 0.5 cum. in volume) hard laterite, hard copra and hard conglomerate or other rock which may be quarried or split with crowbars with casual blasting, if required, for loosening of strata.

(ii) Any rock which in dry state may be hard, requiring blasting but when wet becomes soft and manageable by means other than blasting.

4.4.6. Hard Rock (Requiring blasting) - Any rock or boulder (more than 0.5 cum. in volume), which requires the use of mechanical plant or blasting for excavation or splitting.

4.4.7. Hard Rock (blasting prohibited) - Hard rock requiring blasting as described under 4.4.6 but where blasting is prohibited for any reason and excavation has to be carried out by chiseling, wedging or any other agreed method.

4.4.8. Authority For Classification - The classification shall be decided by the Executive Engineer and his decision shall be final.

4.5 CLEARING, GRUBBING AND PREPARATION OF WORKS AREA -

(i) All excavation areas and dam embankment area including a 6 m wide strip measured beyond and contiguous to the limit line of the area as shown on the drawing shall be cleared and any roots etc. completely removed as specified. All trees down timbers, fencing, bush, rubbish; other objectionable materials and vegetation shall be cleared. All stumps and roots shall be excavated and removed. All roots over 50 mm. in diameter shall be removed to a depth of 90 cm below the original ground surface or as directed by the Engineer - in - charge. Materials thus removed will be burnt or completely removed from the site. All felled timber and fuel shall be properly stacking and handed over to the department when asked for by the Engineer - in - charge. Piling for burning shall be done in such a manner and in such location as to cause the least fire risk. All burning shall be thorough so that the materials are reduced to ashes. Special precautions shall be taken to prevent fire from spreading to the areas beyond limits or the areas specified and suitable equipment and supplies for preventing and suppressing fire shall be available at all times.

(ii) No trees shall be cut from outside of areas designated unless instructed in writing by the Engineer - in - charge and all trees designated outside of the areas actually occupied by the works shall be protected carefully from the damage.

4.6 STRIPPING AND BENCHING UNDER DAM EMBANKMENT:

(i) The entire area of embankment including a 3 m wide strip beyond and continuous with the area of embankment proper as showing in the drawing shall be stripped or benched to a sufficient depth as directed to remove all unsuitable materials. The unsuitable material to be removed shall include loose rock, vegetation, topsoil, sod, and organic silt swamp material and rubbish and any other objectionable materials below the ground surface.

(ii) At location where a river or stream crossed the embankment site, loose sand and gravel and loose boulders shall also be removed as directed.

(iii) Stripped materials shall be disposed off in a manner as may be directed by the Engineer - in - charge and in such a way as not to detract from the finished appearance of the project.

4.7 EXCAVATIONS OF CUT - OFF OR PUDDLE TRENCH UNDER DAM EMBANKMENT:

4.7.1. Procedure for Excavation - A cut off trench or puddle trench as shown in the drawings shall be excavated in the foundation of the dam at the location indicated. This trench shall be excavated to a depth of 0.6 m to 1.2 m. into rock (depending upon the permeability of the rock) or into other impervious stratum as may be approved by the Engineer - in - charge. Accurate trimming of the slopes or the excavation will not be required but the cutting in general shall follow lines as specified in drawings. The area to be excavated shall be unwatered. The water level shall be maintained below the level of excavation in the area and none of the excavation shall be performed in standing water.

4.7.2. Utilisation or Excavated Materials - Trench excavation shall preferably be started after the whole base of the dam or at least the substantial part of it is cleared, grubbed, benched or stripped as required by specifications so that suitable material out of trench excavation can be directly utilised for forming the bank, to maximum possible extent .

4.7.3. Blasting of Rock - No blasting of rock would be permitted for the excavation in hard rock when the excavation reaches within about 60 cm of final levels, if in the opinion of the Engineer - in - charge, such blasting will shatter and disturb the rock below foundation. He may also put similar restrictions, in cases, where damage is apprehended to works in neighbouring area existing or under construction. In such cases rock excavation shall be completed by chiselling and wedging etc.

4.7.4. Material received from Cut- Off Trench or Puddle Trench:

4.7.4.1. The materials, excavated from the trench shall, if suitable, be used in the embankment either immediately or after stock piling as convenient and directed by the Engineer - in - charge.

The suitability or otherwise of the material and zone of the embankment in which it is to be placed will be specified by the Engineer - in - charge on the basis of laboratory tests.

4.7.4.2. Materials excavated from the trench shall not be placed in the embankment till foundation for the embankment has been cleared, stripped and prepared as specified and adequate arrangements made for watering and rolling the layers of earth fill in the embankment.

4.7.4.3. Materials excavated from the trench shall be subjected to the same degree of embankment control as material obtained from borrows pits.

4.7.4.4. The material excavated from the trench which are not suitable for use in the embankment shall be disposed off in a manner as may be directed by the Engineer - in - charge and in such a way as not to detract from the finished appearance of the project.

4.7.5. Cut - Off Trench Filling - Cut off trench shall be back filled with impervious material of the same specification and in the same manner as for the impervious hearting zone of the embankment of the dam in accordance with specifications under para 4.9 But before back filling is started foundation grouting in accordance with specification of Chapter 22 may be completed, where required, unless the Engineer - in - charge directs otherwise.

4.7.6. Puddle Filling:

4.7.6.1. Puddle:

4.7.6.1.1. The puddle shall consist of good retentive clay of best quality free from organic or other foreign material. It should be clean and tough and should be available near the sits as far as possible. The most suitable clay is of the description used for tile making Soft sludgy, peaty sandy, salt or puffy clay should be rejected.

4.7.6.1.2. The clay is to be worked out into puddle before use by turning it over and over again with phowras, watering and treading with men's feet into one plastic homogeneous mass of the toughest consistency until it gets plasticity.

4.7.6.2. Laying of Puddle.

4.7.6.2.1. The puddle shall than be made into balls and thrown into the trench or in any other position required. No more than 15 cm in thickness of puddle shall be deposited in the place at one time and it must at once be thoroughly kneaded by men's feet and incorporated with mass below it so that the whole will be uniform and not in layers.

4.7.6.2.2. The top of puddle shall be kept as level and uniform as possible and shall on no account be allowed to dry. If the surface cracks at any time it shall be dug up and puddle remade.

4.7.6.2.3. Vertical joints across the puddle wall and steps to its side shall be avoided. All joints shall be made by long inclined faces overlapping each other.

4.7.6.2.4. The whole width of puddle trench excavated shall be filled with puddle only so that the puddle gets thoroughly into the interstices of trench walls. The joint near the wall shall be thoroughly kneaded with men's heels.

4.7.6.2.5. On holidays and other days, when works are stopped, labour should be specially employed to keep the surface of puddle wet by sprinkling of water.

4.7.6.3. The puddle filling shall not be done in standing water. Water level in trench shall be kept below the working level by means of pumps, if required.

4.7.6.4. As the surface of the puddle layer dries up, it should be thoroughly consolidated with rammers before a new layer of puddle is laid the surface or the previous layer, if not newly made, should be lightly sprinkled with water by means of watering pots and kneaded.

4.7.6.5. When puddle is finished, it should be immediately covered up in the work or when, this is not possible, it should be covered with approved hearting soil and kept moist.

4.7.6.6. The surface soil if not conforming to approved hearting soil, is to be removed on both sides of the puddle trench for a breadth equal to that of the top of the trench, and for 0.60 m deep, and refilled with selected clay or other material used for the hearting and consolidated in the same way.

This filling is to be carried up with the puddle wall to a height of 0.6 m above ground level and joined with the hearting.

4.8 BORROW AREAS:

4.8.1. All materials required for the construction of impervious, semi pervious or pervious zones of embankment and backfill for cut off/ puddle trench which are not available from cut off/ puddle trench excavation or other compulsory excavation, shall be obtained from designated borrow areas as shown in drawings or as designated by the field laboratory.

The limits of each borrow areas to be used in the various zones of embankment shall be flagged in the field and materials from each borrow areas shall be placed only in the zones for which it has been specified.

The depth of cut in all borrow areas will be designated by the Executive Engineer and the cuts shall be made to such designated depths only. Shallow cuts will be permitted in the borrow areas, if unstratified material with uniform moisture contents are encountered. Each designated borrow area shall be fully exploited before switching over to the next designated borrow pits. Haphazard exploitation of borrow area shall not be permitted. The type of equipment used and the operations in the excavation of materials in borrow areas shall be such as will produced the required uniformity of mixture of materials for the embankment.

Borrow pits shall not be opened within a distance of ten times the height of the dam embankment from the upstream and downstream toes. Borrow pits shall be operated so as not to impair the usefulness or mar the appearance of any part of the work or any other property. The surface of wasted materials shall be left in a reasonably smooth and even condition. Care should be taken in working of the borrow areas in tank basin to ensure that existing impervious blanket material is not completely removed and porous strata exposed.

4.8.2. Preparation of Borrow Areas - All areas required for borrowing earth for embankment shall be cleared off all trees and stumps, roots, bushes, rubbish and other objectionable material. Particular care shall be taken to exclude all organic matter from the material to be placed in the dam embankment. All cleared organic materials shall be completely burnt to ashes or disposed off as directed. The cleared areas; shall be maintained free of vegetable growth during the progress of work.

4.8.3. Stripping of borrow Areas - Borrow area shall be stripped of top soil, sod and any other matter which is unsuitable for the purpose for which the borrow area is to be excavated. Stripping operations shall be limited only to designated borrow areas. Materials from stripping shall be disposed off in exhausted borrow areas or in the approved adjacent areas, as directed.

4.8.4. Borrow Area Watering - Borrow area watering if needed based on laboratory tests will be done by the department as decided by the Engineer - in - charge.

The placement moisture content for proper compaction of earth work should be as near as practicable to optimum moisture content as decided by laboratory tests. However, depending upon the site condition, the nature of the earth of the borrow area, the season of the year, the moisture content of the earth of borrow area will vary over a wide range. Thus it would be necessary to add water to bring the moisture content of borrow area earth to as near OMC as practicable. In Irrigation Projects, watering in borrow areas may be done where watering at the place of fill does not yield required results. Wherever practicable and specially during dry months periodical watering of the borrow area by tankers and mobile units may be done to the extent possible as decided by Engineer - in - charge.

4.9 Dam Embankment:

4.9.1. General - Certain instruments for measuring the performance of the dam during construction and afterwards are proposed to be installed by the department at locations as specified in the drawing or as decided by the Engineer - in - charge. Necessary facilities for the installation and observation of these instruments shall be extended by the agency executing the work. For installation and observation of instruments and for necessary soil tests near the installed instruments, necessary time shall be allowed within placement schedule.

The embankment shall be constructed (exclusive of pitching and backing of chips of filter below pitching) generally to the lines and grades shown on the drawings, but increased by such heights and widths determined as necessary to allow for settlement or shrinkage as specified in para .4.9.9. Also in

order that proper compaction can be done upto the edges of the designed section duly increased for settlement and shrinkage as stipulated above, section will be further widened by 45 cm.. Subsequently after compaction it will be dressed by trimming the slopes to proper section so that the surface on the slopes is also as firm and compact as the top of embankment. The earth thus trimmed could however, be used in the embankment fill. Any material that is lost by rains weathering or other cause shall be replaced.

The dam embankment is divided into zones within which fill materials having different characteristics are to be placed. Placement of fill within these zones as shown in the drawings shall be performed in an orderly sequence and in efficient and workman like manner, so as to produce within each zone, fills having such qualities of density, strength and permeability as will ensure the highest practicable degree of stability and performance of the whole dam embankment.

No bushes, roots, sods or other perishable or unsuitable materials shall be placed in the embankment. The suitability of each part of the foundation for placing embankment materials there on and for all materials for use in embankment construction will be determine by the field laboratory.

The difference in elevations between core and shell zones of the dam embankment at any cross - section above the embankment foundation shall not exceed 0.6 m unless specifically authorised by the Engineer - in- Charge. The embankment for each zone shall be maintained in continuous and approximately horizontal layers in the reaches programmed for construction in that season. Where however, due to some constraints the dam has to be constructed in discontinuous portions or reaches, the slopes of the bonding surface parallel to dam axis between the previously completed portions of the dam embankment and the materials to be placed in each zone shall not be steeper than 3 to 1 in core, and 2 and 1/2 to 1 in other zones.

4.9.2. Preparation of foundation - Foundation preparation shall be done subsequent to stripping and excavation, if any. All portions of excavation made for test pits or other subsurface investigations and all other existing cavities found within the area to be covered by earth fill or of core and shall zones, which extend below the established lines of excavation for embankment foundation, shall be filled with earth fill of the corresponding zone of the embankments. All test pits within a distance of 10 times the dam embankment from the upstream toe shall be filled by impervious material. No material shall be placed in any section of the earth fill portion of the dam embankment until the foundation for that section is suitably prepared and has been approved by the Engineer - in - charge.

The surface of each portion of the Foundation immediately prior to receiving any material for the earth fill shall be moist and sufficiently cleaned to obtain a suitable bond with the embankment.

Pools of standing water will not be permitted in the foundation of the embankment and shall be drained out prior to placing the first layer of the embankment.

(a) Rock Foundation - The treatment of the rock surface under the dam shall be so done as to ensure a tight bond between the impervious core and foundation, for which the following procedure shall be followed.

(1) Before the grout curtain is installed, the area of the rock surface which is to be in contact with the impervious core of the dam shall be exposed with rough excavation. Hard rock projections and overhangs shall be removed. If blasting is to be resorted to, care shall be taken to avoid objectionable shocks to foundation rocks and abutments. As far as possible, the whole contact area of foundation rock and abutments after rough excavation shall be exposed at one time to enable examination of rock surface characteristics and planning the method or treatment. Curtain grouting where required shall be carried out in accordance with provision under relevant para of specifications of Chapter 22 " Drilling and Grouting "

(2) Cleaning and Shoveling - After the grouting operations are over, the rock surface shall be thoroughly cleaned. Pockets of sand and gravel and other soils shall be removed by hand shoveling and soft erodible seams and localised decomposition cleared out as deep as possible. Loose rock shall be removed by wedging and hand picking. Layers or grout spilled from grouting operation shall be chipped out and removed. Finally, the hand cleaned surface shall be thoroughly washed with powerful water jets to remove the fines which would have worked into the seams of the rock and obtain a clean surface. Compressed air jets shall be used as a final step in the clean up operation.

(3) Sealing cracks - Deep pot holes or pockets shall be filled with hand compacted soil or concrete. If the rocks surface in the bottom and sides of pot holes is cracked, the cracks should be sealed with cement grout. If the rock surface contains too many closely spaced pot holes, the entire rock surface shall be covered with concrete. A clay paste may be used in the smaller cracks. All the cracks and joints and shear seams or other incompetent materials that are exposed in the cut off trench shall be scooped out to the

greatest depth practicable (Not less than twice their width at the surface) with the aid of trowels, bars and cleaned with air water jets and then filled with slush grout. Slush grout shall consist of cement and sand thoroughly mixed in a proportion, 1 part of cement to 2 parts of sand by volume with sufficient water to produce a highly plastic and buttery mix.

Foundation rock which is fairly impervious but has a very rugged surface shall be treated by laying core material at a moisture content slightly above the optimum in thin layers and compacted with mechanical equipment / small tampers to ensure that all irregular depressions in the rock surface have been filled with soil to create an effective / complete bond.

The moisture content and layer thickness shall be specified by the field laboratory. Any open crack in the rock surface shall be specified by the field laboratory. Any open crack in the rock surface shall be sealed with cement grout by appropriate means. Fault zones or larger cracks shall be dug out to a depth as determined by the Executive Engineer and backfilled with concrete.

(b) Soil Foundation - Soil foundation shall be scarified and loosened by means of a plough ripper or other methods to a depth of about 15 cms. to 20 cms. to the satisfaction of the Executive Engineer. Roots or other debris turned up during scarifying shall be removed from the entire foundation area for the fill. It shall then be moistened to slightly above the optimum moisture and compacted by required number of passes of the compaction equipment to the same percentage of compaction as the core. The purpose of higher than optimum moisture is to ensure forcing of the soil into any unseen soft zones just below the surface. The first few lifts of fill for the embankment shall be carefully placed, for the surface will still be rather irregular. If possible, heavy rubber tyred rollers should be used for compaction because they will follow the irregular surface and not bridge over small low areas, as other types of rolling equipment will do. Layers 10 cms to 15 cms thick with moisture content 1 to 2 percent above optimum moisture content must be used to ensure uniform compaction and a satisfactory intimate bond between the foundation soil and the fill materials especially under the central core. The layers shall be composed of the most impervious materials, under the central core zone.

(C) Sand Foundation - The foundation sand shall be tested for its natural relative density. In reaches where the relative density is less than 70%, the foundation sand shall be densified by any of the approved methods to obtain a minimum relative density of 70%. Until the foundation has been tested and the relative density found to exceed 70%, earth fill shall not be allowed to be placed. This is necessary to minimise the effects of any structural readjustments in a loose foundation.

4.9.3. Earthfill Materials - The materials for the respective zones of embankment shall be obtained from borrow areas required for obtaining the desired gradation in the depth of cut in the borrow areas required for obtaining desired gradation in the materials. In general, all materials from a particular borrow area shall be a mixture of materials obtained for the full depth of cut. Where in a borrow area the sub - stratum occurs in well defined layer differing considerably in mechanical analysis, so that mixture is not suitable for any particular zone, the materials shall be excavated layer wise by scrapers or other suitable means and the materials placed in the zone for which it satisfies the requirements. Where it is not practicable to obtain a mixture of materials, the finest and most clayey material shall be placed in the cut- off trench and the central upstream portion of the embankment. The intermediate material shall be placed near the outer slopes of the embankment. No material containing a high percentage of plastic clay shall be used in the embankment without being mixed with coarser material.

Chemical and Physical tests of soils in embankment shall be carried out to ensure that the soil does not contain (a) soluble lime contents (b) soluble salt contents of cohesionless fines, in quantities harmful to the embankments.

4.9.4. Placing earthfill - The distribution and gradation of the materials throughout earth fill shall be as shown on the drawings or as directed. The fill shall be free from lenses, pockets, streaks or layers of materials differing substantially in texture or gradation from the surrounding materials. The combined excavation and placing operations shall be such that the material when compacted in the earth fill will be blended sufficiently to produce the best practicable degree of compaction and stability. Successive loads of materials shall be dumped on the earth fill so as to produce the best practicable distribution of the material. The various zones shall be clearly delineated on the embankment and the materials from the borrow areas placed accordingly.

The clay blanket shall be laid in a manner similar to clay core and compacted to same degree or compaction at optimum moisture content.

Particular care shall be taken to ensure that materials are not so placed as will be conducive to the formation of intermittent relatively impervious blankets in the shall zone, which will interfere with the satisfactory drainage.

No stone, cobbles or rock fragments having maximum dimensions or more than 10 cms. shall be placed in the earth fill (casing only). Such stones and cobbles shall be removed either at the borrow pit or after being transported to the embankment but before the materials in the earth fill are rolled and compacted. Such stone and cobbles shall be used in the riprap or rock toe of the dam embankment, if suitable or wasted as directed. The materials shall be placed in the earth fill in continuous horizontal layers not more than 15 cm in thickness after being rolled as herein specified. Higher thickness or layers may also be permitted, if suitable compaction units such as vibratory compactors are used to give required density under optimum moisture content, but in no case the compacted thickness of the layer shall exceed 25 cm. The extent of layers shall be determined in the field by test section. During construction, a small transverse slope from centre towards edges should be given to avoid pools of water forming due to rains. If in the opinion of the Executive Engineer the surface of prepared foundation or the rolled surface of any layer of earth fill is to dry or smooth to bond properly with the layer of materials to be placed thereon, it shall be moistened or worked with harrow, scarifier or other suitable equipment, in an approved manner to a sufficient depth to provide a satisfactory bonding surface before the next succeeding layer or earth fill materials is placed. If the rolled surface of any earth fill is found to be too wet for proper compaction of the layer of earth fill materials to be placed thereon, it shall be raked up and allowed to dry, or be worked with harrow, scarifier or any other suitable equipment to reduce the moisture content to the required amount, and then it shall be compacted before the next succeeding layer of earth fill materials is placed. The concrete or masonry surfaces against which earthwork is to be placed shall be cleared and moistened prior to placing of the earth fill, clay leaping of plastic consistency be adopted to ensure proper bond between the earth fill and the concrete / masonry. The foundation adjacent to the concrete structures shall be thoroughly cleared of loose materials and moistened. In placing the earth fill on rock foundation, the foundation shall first be prepared as detailed earlier. Care shall be taken in placing the first layer of the fill that no damage is caused by the hauling machinery, which will get concealed by the spread layer of the fill. The soil for the layer shall be at a moisture content sufficient to enable satisfactory bonding of the fill with the rock surface.

In case the whole length of embankment is not constructed simultaneously and only a portion of the embankment is constructed during one season the following procedure shall be adopted.

The incomplete ends of embankment shall be placed at a slope not steeper than 4:1 to permit satisfactory bonding with the portion of the embankment, which is constructed later. Old surface should be stripped or benched in accordance with the direction of the Engineer- in - charge.

4.9.5. Weather Conditions - The embankment material shall be placed only when the weather conditions are satisfactory to permit accurate control of the moisture content in the embankment materials. During that part of the construction period when the top surface of the embankment may be subject to rainfall causing cessation of work, it shall be graded and rolled with a smooth wheeled rollers to facilitate runoff. Prior to resuming work, the top surface should be slightly scarified and moistened or allowed to dry as necessary and approved by the Engineer- in - charge. If the cessation due to any reason, is for a considerable period, top layer shall be stripped to the required depth as may be directed by the Engineer - in - charge, so as to remove any vegetable growth, loose silt or sand washings or other objectionable matter.

4.9.6. Moisture Control - The water content of the earth fill material prior to and during compaction shall be distributed uniformly throughout each layer of materials between -2 to +1 of the optimum moisture content for casing material and between 0 to +2 for hearting material. Moisture determination of soil as well as needle moisture determination of soil shall be carried out as per IS : 2720 (pt. II) - 1973, Sec. 1 and designation E22 of USBR/ Earth manual 1968 respectively.

Laboratory investigations may impose some restrictions on the lower limits of the practicable moisture contents on the basis of studies on consolidation characteristics of soils in embankment. Hereinafter, the term range of optimum practicable moisture content shall refer to the value as described above. As far as practicable, the materials shall be placed at proper moisture content. If additional moisture is required it shall be added by sprinkling water before rolling of a layer. If the moisture is greater than required, the material shall be spread and allowed to dry before starting rolling. Moisture control shall be strictly adhered to. The moisture content shall be relatively uniform throughout the layer of material. If necessary, ploughing, disking, harrowing or blending with other materials may have to be resorted to, to obtain uniform moisture distribution,

if the moisture content is more or less than the range of optimum practicable moisture content, or if it is not uniformly distributed throughout the layer, rolling and adding of further layer shall be stopped. Further work shall be started again only when the above conditions are satisfied.

The moisture content of the earth fill placed against any rock outcrop or any structure shall be slightly above the optimum to allow it to be compacted in to all irregularities of the rock and this shall be determined by the field tests.

4.9.7. Compaction and watering:

4.9.7.1. Compaction Equipments - While the specification below provide that equipment of a particular type & size is to be furnished and used, it is contended that the improved compaction equipment as may be most suited to the prevailing site conditions and the programme of construction shall be used. The broad details of the equipments are given below.

4.9.7.1.1. Tamping rollers / Vibratory compactors shall be used for compacting the earth fill .The sheep foot rollers shall meet the following requirements.

(I) **Roller Drums -** Each drum of a roller shall have an outside diameter of not less than 150 cm and shall be not less than 120 cm. not more than 180 cm in length. The space between two adjacent drums, When on a level surface shall not be less than 30 cm nor more than 38 cm. Each drum shall be free to pivot about an axis parallel to the direction of travel. Each drum shall be equipped with a suitable pressure relief valve to prevent excessive pressures from developing in the interior of the roller drum.

(II) **Tamping Feet -** Atleast one tamping foot shall be provided for each 65 sq. cm of drum surface. The space measured on the surface of the drum between the centres of two adjacent tamping feet shall not be less than 230 mm. The cross sectional area of each tamping foot shall be not more than 65 sq.cm. at a plane normal to the axis of the shank, 150 mm from the drum surface and shall be maintained at not less than 45 sq.cm. nor more than 65 sq.cm. at a plane normal to axis of the shank 200 mm from the drum surface.

(III) **Roller Weight-** The weigh of the roller when fully loaded shall not be less than 7,091 Kg and the ground pressure when fully loaded shall not be less than 40 kg/cm². required to obtain the desired compaction. Tractor used for pulling rollers shall be of 50 H.P. to 65 H. P., power to pull the rollers satisfactorily at a speed of 4 kms/per hour when the drums are fully loaded with wet sand ballast. During operation of rolling, the spaces between the tamping foot shall be kept clear of materials sticking to the drum which cold impair the effectiveness of the tamping rollers.

4.9.7.1.2 Rolling - (i) When each layer of material has been conditioned so as to have the proper moisture content uniformly distributed through the material, it shall be compacted by passing the tamping roller. The exact number of passes shall be designated by the field laboratory after necessary test. The layers shall be compacted in strips overlapping not less than 0.6 m. The rollers or loaded vehicle shall travel in a direction parallel to the axis of the dam. Turns shall be made carefully to ensure uniform compaction. Rollers shall always be pulled.

(ii) If the foundation surface is too irregular to allow the use of large roller directly against any structure or rock out - crop, the roller shall be used to compact the soil as close to the structure or the out crop as possible and the portion of the embankment directly against the rock or the structure shall be compacted with pneumatic hand tampers in thin layers. Sheep foot roller shall not be employed for compaction till the thickness of the layers compacted by other mean is greater by 30 cm than the depth of the foot of the roller drum.

4.9.7.1.3. Tamping -Rollers will not be permitted to operate within 1.00 metre of concrete and masonry structures. In location where compaction of the earth fill material by means of roller is impracticable or undesirable, the earth fill shall be specially compacted as specified herein at the following locations.:-

1. Portions of the earth fill in dam embankment adjacent to masonry structures and embankment foundation designated on the drawing as specially compacted earth fill.
2. Earth fill in dam embankment adjacent to steep abutment and location of instruments.
3. Earth fill at locations specially designated.

Earth fill shall be spread in layers of not more than 10 cm. in thickness when loose and shall be moistened to have the required moisture content as specified. When each layer of material has been conditioned to have the required moisture content, It shall be compacted to the specified density by special

rollers, mechanical tampers or by other approved methods and all equipment and methods used shall be subject to approval based on evidence of actual performance and field compaction tests. The moisture control and compaction shall be equivalent to that obtained in the earth fill actually placed in the dam embankment in accordance with the specifications.

4.9.7.1.4. Watering - Watering of earthwork for consolidation shall be carried out by the department or by the contractor as per clubbed item of schedule. The arrangements for storage, pumping equipment and laying of suitable pipe lines of adequate capacity on upstream and downstream of the dam will be made. The connections will be provided at regular intervals in the main pipeline to connect to the off-take lines having valves to control the flow through rubber hoses. The whole system will be such and so laid out that regular flow of water is ensured on the dam at all times. The pipeline will be required to be raised as and when required with the raising of the earthwork on the dam.

4.9.8. Dressing Slopes. The outside slopes of the embankment shall be neatly dressed to lines and grades as placement of fill progress.

All humps and hollows varying more than 15 cm from the neat lines of the embankment shall be regraded. Material used to fill depression shall be thoroughly compacted and bonded to the original surface. Slopes shall be maintained until final completion and acceptance. Any material that is lost by rains, weathering or other cause shall be replaced at the cost of agency executing the work.

4.9.9. Settlement Allowance - In the earth fill embankment watered, rolled and compacted at optimum moisture content and at dry density expressed as percentage or Proctor's maximum dry density as given in Appendix - 1, settlement allowance of 1% and 2% of the designed height for unyielding (rock) and compressible (Soil) foundations respectively shall be provided. The base width of the dam will not be increased to maintain the design slopes indicated in the drawings for the additional height as settlement allowance, but the following procedure will be adopted.

Settlement allowance will be calculated at various levels. Where the slope is to be changed and elevations including settlement allowance will be derived. The embankment width at the designed levels remaining same. The edges of embankment at the increased elevation (including settlement), when joined with the point where the slope has changed earlier below shall give the slope to be adopted for construction.

If the embankment is raised in more than one season, provision for settlement shall be made in the last season's construction by slight steepening of slopes near the top.

4.10 TOE DRAINS -

Pitched toe drains with filter will be provided throughout the length of the dam at the downstream toe of earth dam as indicated in the drawings and as per the details shown therein. The layer of horizontal filter under the casing portion of dam shall be extended in the toe drains to specified thickness. The filter shall be watered and tamped with hand tampers.

The useful excavated material out of the toe drain shall be suitably utilised on the dam as directed by the Engineer - in - charge.

4.11 ROAD SURFACES AND PARAPETS -

(i) Road shall be constructed at the top of the earth dam and other locations as indicated in the drawing. The roadway shall be as indicated in drawing. The construction shall be as specified for the highway by I.R.C. or as directed by the Engineer - in - charge.

(ii) The parapets shall also be constructed after allowing sufficient time for the embankment to undergo the usual post construction settlement in order to avoid cracking of the walls due to differential settlement.

4.12. FILTER:

4.12.1 Base Filter Blankets:

4.12.1.1. Where indicated in the drawings, filter blankets shall be laid on the base under the downstream portion of the earth embankment. The number of layer in the filter blanket or seepage drains and thickness of such layer shall be as specified in the drawing. Filter shall be placed and tamped into place in such a manner that mixing of filter with foundation or backfill materials will not occur.

4.12.1.2. The filter material shall consist of clean, sound and well-graded aggregate. The material shall be free from debris, wood, vegetable matter, decomposed rock and other deleterious matter. The gradation of each filter layer shall meet the following requirements with respect to the material to be protected and also with respect to the adjacent filter layers.

- (i) $\frac{\text{D - 15 of the filter}}{\text{D - 15 of the base material}} = > 4 \text{ and } < 20$

Provided the filter does not contain more than 5 percent of material finer than 0.075 mm (No. 200 sieve)

- (ii) $\frac{\text{D - 15 of the filter}}{\text{D - 85 of the base material}} = < 5$

- (iii) $\frac{\text{D - 50 of the filter}}{\text{D - 50 of base material}} = < 25$

(iv) The grain size curve of the filter shall be roughly parallel to that of the base material. In the above, D-15 is the size at which 15 percent of total soil particles are smaller, the percentage being by weight as determined by mechanical analysis. The D.- 85 size is that at which 85 percent of the total soil particles are smaller. It shall be laid in single layer or in layers as per the drawing if more than one filter layer is required, the same criteria shall be allowed. The finer filter is considered as the base material for selection of the gradation of the coarser filter.

(v) In order to prevent segregation and bridging of large particles, (the maximum) particle size shall not exceed 75 mm .

The requirement for grading of the filter shall be established by the field laboratory on the basis of mechanical analysis of adjacent materials.

The material brought to the site shall be subjected to the aforesaid tests in the laboratories at the project site. The result shall be final and binding and all material not conforming to the requirement so determined shall not be permitted, for use on the said works.

(vi) The following gradation is tentatively suggested but is subject to modifications after further laboratory tests: -

- | | |
|-------------------------------------------------------------------------------|-----------------------------------------------------------------|
| (a) For filter material in contact with foundation or earth fill material | Well graded coarse sand & gravel passing 12 mm screen |
| (b) For middle layer of filter blanket & for layers in contact with rock fill | Coarse gravel passing 75 mm screen and retained on 12 mm screen |

4.12.1.3 Placing:

4.12.1.3.1. The foundation shall be cleared, stripped as specified in paras 4.5 and 4.6 and SC layers of specified thickness as shown in the drawing shall be laid wherever there is clay in the dam seat, before laying the base filter.

4.12.1.3.2. The filter material shall be deposited in horizontal layers of thickness not more than 15 cm after compaction to achieve relative density not less than 70 % . The thickness of filter layer shall

be increased to 30 cm if compaction is performed by treads of crawler type tractors, Surface Vibrators, or similar equipment. Thickness of layer shall, however, not be more than the penetrating depths of the vibrators, if compaction is performed by internal vibrator. During or immediately prior to compaction, the material in each layer shall be thoroughly wetted.

4.12.1.3.3. The relative density of the compacted material shall be not less than 70 % as determined by relative density tests of cohesionless soils as per procedure given in IS: 2720 (Part XIV)- 1983.

4.12.1.3.4. Extreme care shall be taken in placing material in the filter zone as to obtain a fill, free from lenses, layers and streaks of segregated materials.

4.12.1.3.5. After compaction of the filter blanket, the earth fill material shall be placed in 10 cm, layers and tamped by hand at optimum moisture or compacted by smooth rollers or power compactors as directed by the Engineer - in - charge. Sheep foot rollers shall not be used till earthwork has been laid and compacted to a thickness of 60 cms over the filter blanket. However, the compaction of the earthfill in the initial 60 cm thickness shall be subject to the same quality control regarding to moisture content and dry density as for the rest of the embankment.

4.12.2. Chimney Filter - Vertical inclined filter of the dimension specified in drawing shall be constructed on the downstream face of impervious core. The thickness of chimney filter shall be as shown in the drawings. Materials used shall be clean, sound and durable and shall be free from silt roots, bush and other impurities. Filter materials shall be laid in 30 cm layers and shall be thoroughly wetted and compacted by pneumatic tyred rollers or other approved equipments. Materials for filter shall be compacted to obtain a minimum relative density of 70 %. The filter shall satisfy the filter criteria as given in para 4.12.1.2. for base filter blankets.

4.12.3. Seepage Drains - The seepage drains shall be excavated to the size and bed grade as shown in the drawings so as to allow for easy flow of seepage from the hearting toe to the open drains. These shall be refilled with layers of sand gravel or broken metal and boulders as shown in the drawings. In this case greatest care will have to be taken to see that filter media do not get mixed up.

4.13 RIP - RAP ON THE UPSTREAM SLOPE OF EMBANKMENT:

4.13.1. Hand Placed Rip - Rap:

4.13.1.1. Rip - rap shall be hand placed on the upstream slope of the dam embankment over backing of specified filter layers. The thickness of Rip - rap layer shall be as indicated in the drawings.

4.13.1.2. Stone for Rip - rap shall be hard and durable and shall not crumble on long exposure to water frost and air.

4.13.1.3. Procedure for Placing Rip - Rap - The hand placed Riprap shall consist of one-man stones laid on edge. Starting at the bottom of the slope the stone shall be laid compactly with a minimum of joints and so matched and inter locked that they shall be keyed together with staggered joint space. Rock fragments and spall shall be driven into interstices to wedge the Riprap in place. The wedging shall be done with the largest chip practicable, each chip being well driven home with a hammer so that no chip can be removed by hand. Very irregular projection shall be knocked off so that the Riprap presents a reasonably uniform surface free of loose stones.

4.13.1.4. Hand placed Riprap should preferably be laid in one course such that the layer thickness is same as the stone size. However at least 80 percent of the area of Riprap should have stones weighing more than 45 kg. Such stone should be spread uniformly in the area, where such stones are not sufficient to cover the entire thickness of Riprap; the same may be laid in two layers.

If two layers of stones are used, header stones extending through both layer and spaced at about 1.5 m. shall be used. Also of the two layers, the top layer shall be of larger stones. The size of the smallest side of the header stone shall not be less than 150 mm and its length shall be equal to the thickness of the

Riprap plus 150 mm., so that the header stone would project above the general top surface of the Riprap by about 150 mm.. Such a projection will break the wave force and would also facilitate easy identification of the headers stones. If header stones of full length are not available from the quarry, concrete blocks of necessary size, length and shape may be manufactured for the purpose.

In case, if stone of requisite size are not available and smaller stones / boulders locally available are required to be used; the Riprap should be laid in panels formed by constructing profile walls. A portion of the area between the panels may be grouted by pouring fluid cement mortar worked into the Riprap.

Hand placed Riprap may be laid flat or laid with projections (Needles) .

4.13.1.5. The Riprap shall be placed along with the fill so that a minimum of breakdown will occur during placing and spreading.

4.13.2. Dumped Rip-Rap:

4.13.2.1. The minimum thickness of dumped rock Riprap and average rock size shall be as shown in Table 1. The thickness of Riprap shall in no case be less than 450 mm.

TABLE 1 : Minimum Thickness of Dumped Rip-Rap

Maximum wave height metre	Minimum average rock size (D ₅₀) mm	Minimum Riprap Thickness mm
0 to 1.5	300	600
1.5 to 3.5	400	750
above 3.0	700	1000

4.13.2.2. The most important criteria in Table 1 is the minimum average rock size (D₅₀)of Riprap. For example, for waves of waves of 2 m in height the Riprap should be composed of rocks, half of which by weight are equal to or larger than more or less equidimensional rock with average diameter of 400 mm. The rock used for Riprap shall be well graded from a maximum rock roughly equal to 1.5 times the average size to 50 mm.

4.13.2.3. Procedure for Placing Rip- Rap - Dumped Riprap shall consist of boulders or blasted rock fragments; it shall be dumped in place mechanically on a properly graded filter layer. The full thickness of dumped Riprap shall be dumped in one layer. It shall either be dumped over the upstream face from the embankment level as the embankment is being raised up or after the embankment had been completed. When placed during the construction, the Riprap layer should be kept a few meters lower than the construction surface. When placed after the embankment is completed, the rock should be taken to the crest of the dam in trucks and then lowered down the slope by suitable mechanical device. The rock shall not be allowed to drop down the slope in a chute or be pushed down the slope, since these operations result in excessive segregation. After dumping, the rock should be worked manually with bars or other equipment to achieve a well-packed and tidy surface.

4.13.3. Grade Filter Underneath Rip- Rap -

4.13.3.1. Graded filter shall consist of atleast two layers of filter material (coarse and fine). The thickness of each layer shall be as specified in the drawing.

4.13.3.2. The graded filter shall consist of sand and crushed stone as shown in the drawing Sand used shall be clean sound and durable and shall be free from silt roots, brush wood and other impurities. Sand used shall be of size passing 4.75 mm screen. Crushed stone used for filter shall consist of rock fragments reasonably graded upto 15 cm in maximum dimension.

4.13.3.3. Gradation requirement for the coarse filter material with respect to Riprap material should conform to the criteria that D₈₅ size of the coarse filter material shall not be less than 1/10 of D₁₅ size of the Riprap material. The gradation requirements for the fine filter with respect to embankment material

should conform to the criteria that D15 size of the fine filter material shall not exceed 5 times the D 85 size of the retained embankment material .The two layers of filter shall also satisfy these criteria with respect to each other. Where the embankment material satisfy this criteria with respect to coarse filter fine filter could be omitted.

4.13.3.4. Before placing of filter material, The embankment shall be trimmed neatly to slope and grades as indicated on the drawing .The filter material shall be placed in layers of uniform thickness and care shall be taken to avoid segregation of coarse and fine material in each layer, formation of pockets and mixing of material of one layer with material of another layer or earth fill.

4.13.4. - Tolerance: The tolerance on the nominal thickness of Rip - rap enforced on the performed profile shall be 10 percent.

4.13.5. - Dry Stone Pitching:

4.13.5.1. - The quality stones for pitching shall be in accordance with para 4.13.1.2.

4.13.5.2. - The depth of stones shall be about equal to the specified thickness of pitching and shall generally be not less than 0.014 cum or 0.021 cum as specified in the appropriate item of USR or other sizes as ordered by the Engineer-in-Charge having regard to the nature of stones being quarried. The small size stones/ spalls required for pitching and wedging shall be brought to the site only to the required extent and they shall not to be used in two or more thickness as a substitute for the stones of full thickness. A large amount of the stones for pitching shall be obtained from the required excavation for other parts of the work. Additional rock as required shall be obtained from rock quarries.

4.13.5.3. Placing: -

4.13.5.3.1.- Backing of filter and / or spalls where specified on drawing shall be placed only after the underlying slope shall be trimmed neatly to the slopes and grades established on the drawings .The lowest course of pitching shall be started from the toe wall or the line of pinheaders at the toe of the slopes as may be specified on the drawing and the pitching laid course by course up the slope.

4.13.5.3.2.- Projecting corners shall be knocked off with the hammer so as to make a rough joint at the base. The stone shall be laid on end with broadest base down and length normal to the slope and carefully bonded in all directions and firmly bonded on the backing of filters where provided. The stones shall be packed with hammer or mallet closed against each other, their general line being approximately perpendicular to the slope of the underlying surface.

4.13.5.3.3. - After the stones have been fixed as above, the interstices shall be filled with well fitting chips driven home.

4.13.5.3.4. - The general face slope of the pitching when completed shall be as specified in the drawing subject to the tolerance as given in para 4.13.5.1. below . The final surface of the pitching shall be clear of all refuge.

4.13.5.3.5. - Tolerance - The provision in para 4.13.4 shall apply.

4.13.6. Grouted Stone Pitching:

4.13.6.1. - The specification of para 4.13.5.1. to 4.13.5.3. shall be followed except for the use of stone chips or quarry spalls as described in para 4.13.5.3.3.

4.13.6.2. - After the pitching stones are laid as described in para 4.13.5.3.2, the Interstices shall be filled with mortar of specified mix. The mortar shall be forced into the joints with the help of 6 mm. rods so

as to ensure that the mortar reaches upto the base. The joints shall then be finished flush with the help of trowel.

4.13.6.3. - The surface of the pitching shall be cleaned of all loose mortar droppings, etc., The joints shall be cured for at least seven days after the initial setting time of one day.

4.13.7. Dry Picked Up Boulder Pitching:

4.13.7.1- The boulders used in this type of pitching shall consist of the rolled rock masses directly picked up in their natural form from the river or the nalla beds. The boulders shall be hard dense and resistant to abrasion. The size of the boulders in at least one direction should not normally be less than 22 cm. Also the least dimension of such boulders in any direction should not be less than 10 cm. The smaller size boulders/ gravels required for packing and wedging shall be brought to the site only to the required extent and shall not be used in two or more layers as a substitute for the boulders of full thickness.

4.13.7.2 - Placing:

4.13.7.2. 1. - Over the backing of filter as may be specified in the drawing, the boulders shall be placed such that the direction in which the size of boulder is around 22 cm is placed normal to the surface of under layer. Also the boulders shall be laid with broadest base down and carefully bonded in all directions .

4.13.7.2.2. - After the boulders have been fixed as above, the interstices shall be filled with well fitting smaller size boulders, gravel driven home.

4.13.7.2.3. - The provision of para 4.13.5.3.4. Shall be applicable here also.

4.13.8. Dry Quarried Boulder pitching:

4.13.8.1. - The specification as in para 4.13.6.1. shall be followed except that the boulders of required size shall be obtained by breaking big size boulders.

4.13.8.2. - Placing - The specifications as at para 4.13.6.2.1. to 4.13.6.2.3. shall be followed.

4.13.8.3. - Tolerance -The specifications as at para 4.13.4. shall apply .

4.14. ROCK TOE:

(i) The rock fill shall consist of free draining mixture of rock fragments of sizes from 75 mm to 250 mm. A large amount of material may be obtained from required excavation for other parts of the work. Additional as required shall be obtained from rock quarries.

(ii) Successive loads of material shall be dumped as to secured the best practicable distribution materials. The large rock fragments shall be placed on the outer slopes and the smaller fragment shall be placed towards the earth fill side. In general the downstream toe shall be placed in the manner to be approved by the Engineer - in - charge.

(iii) The rock fill shall be placed in horizontal layers not exceeding 90 cm in thickness. The completed fill shall be stable and no large unfilled spaces shall be present in the fill.

(iv) Large voids, shall be not be allowed on the downstream face of the rock - toe, so as to prevent choking by the spilling of earth, rain cuts etc. during and after construction. Such voids shall be properly packed with stone chips of suitable sizes. The surface of the rock - toe shall be kept clear of all earth and debris so as not to choke its full drainage capacity.

(v) The filter layers to be provided behind and below the rock - toe shall satisfy the requirements of para 4.12.1.2.

4.15 - INSPECTION AND TESTS:

4.15.1 General - The Executive Engineer shall maintain and exercise thorough check on the quality of fill material delivered to the dam and shall arrange to obtain the data and in-situ proportion of the material after compaction with designed assumptions. To achieve these objectives, a program of fill testing and inspection shall be planned to affect quality control.

4.15.2. Scope of Testing and Inspection Required:

Field control of fill material will require visual and laboratory checks. The checks on the effectiveness of placement and compaction procedure will required to be made by field density - tests at prescribed intervals.

4.15.3. Before Compaction:

Materials delivered to the fill shall be visually examined and their properties estimated by way of inspection. These checks shall include.

(a) Borrow Areas:

- (i) Excavation of borrow areas shall be limited in extent and depth as indicated on plans.
- (ii) Estimation of moisture contents of materials by visual examination and feel.
- (iii) Samples shall be taken for laboratory analysis in case the soil is of different characteristics.

These inspection checks shall be supplemented by sampling the materials at prescribed minimum intervals and by testing the samples in the laboratory for gradation and moisture content.

(b) Embankment:

- (i) Water content tests shall be carried out in the laboratory while placing the fill materials.
- (ii) Moisture content shall be controlled by adding water or aerating the soil according to laboratory test.
- (iii) It shall be ensured that the methods of dumping, spreading and moisture conditions are such that which results in reducing segregation and or variation of moisture content to a minimum.

4.15.4 During Compaction:

It is intended that the checks on operations during compaction shall verify.

- (i) That the layer thickness of the materials is as specified.
- (ii) That the fill is compacted by the specified number of passes of the specified machinery.
- (iii) That no excessive rutting, weaving or a scaling of the fill occurs during compaction.

4.15.5. After Compaction:

The condition of the fill after compaction shall be observed and recorded particularly with respect of rutting or weaving. However, the properties of materials after compaction shall be determined primarily by field density tests. Dry density attained shall satisfy the compaction standards as per Appendix. I

4.15.6 Frequency of Testing:

4.15.6.1. The frequencies for various tests for earthwork shall be in accordance with Appendix 6.02 of the M. P., W. D. Manual 1983 Vol. Part II.

4.15.6.2 Special attention shall be given to the following locations where insufficient compaction is likely to occur: -

- (i) The junction between areas of mechanical tamping and rolled embankment along abutments or cut off walls.
- (ii) Areas where rollers turn during rolling operations.
- (iii) Areas where too thick a layer is being compacted.
- (iv) Areas where improper water content exists in a material.
- (v) Areas where less than specified number of roller passes were made.
- (vi) Areas where dirt - clogged rollers are being used to compact the materials

- (vii) Areas where over sized rock which has been overlooked is contained in the fill.
- (viii) Areas where materials have been placed when they contained minor amounts of frost, or at nearly freezing temperatures.
- (ix) Areas that were compacted by rollers that have possibly lost part of their ballast.
- (x) Areas containing materials differing substantially from the average.

4.15.7 Record and Reports - Record of borrow area materials and embankment placing operations be maintained in order to have a continuous check on the suitability and availability of fill materials and quality of the fill. Thus, it will be possible to have complete description of materials in any portion of the embankments. The records shall be maintained in the form specified in Appendix. - II.

4.15.8. Field Test Data - Records of field test data results should be presented in the form of statistical analysis sheets and summary sheets in order to provide control required for enforcement of statistical requirements of the specifications.

The test data summary sheets and inspection reports be used to form the basis of construction control report, which should be issued from the site at fortnightly intervals during construction season. The report would contain narrative accounts of the progress and problems of fill construction, statistical analysis of test data and photograph of the fill operations.

4.15.9 Embankment Test Section - Placement of compaction methods specified will have to be verified by test embankment section to be built prior to starting of fill operations or at an early stage of dam construction. The initial stage of dam construction itself could be made to serve the purpose of test embankments. The test sections referred herein shall be used to establish:-

- (a) Layer thickness of fills materials.
- (b) Optimum practicable moisture content.
- (c) Number of passes of the sheep foot roller, or weight of vibratory rollers vis-a-vis number of passes for effective compaction.

When an appreciable change in material occurs, additional test sections shall be made during construction. The procedure for construction of the test embankment section is as follows.

(i) Select a location on the embankment where uninterrupted placing operations are being performed. This area 15 m by 30 m should be carefully worked and referenced so that its limits will be easily recognised. In order to expedite the determination of moisture content to be used, more than one test section may be established on the embankment at the same time.

(ii) During construction of the test section which will most probably continue for several shifts, a complete record of the procedure should be kept. This record should include the number of layers placed, the spread thickness of each layer, the moisture content, at which the materials were rolled, the designated (No. 1, No. 2, etc.) of the rollers used, the condition of the rollers (clean or dirty), the action of the materials being rolled (such as wavy under the rollers, the amount of penetration of the roller teeth after different number of roller trips etc.) and the borrow pit location from which the materials came.

(iii) Check the rollers to make certain that they met all the requirements of the specifications.

(iv) Determine the required spread thickness of layer that will compact to the specified thickness after rolling specified number of times and maintain this thickness as long as number of roller passes is kept the same.

(v) Using the available data from borrow pit investigations of the materials to be used in the test section, the optimum moisture content as determined by laboratory tests will be known and 3 percent less than this moisture content should be used in the first 3 or 4 layers rolled.

(vi) After 3 or 4 layers have been placed at 3 percent less than the laboratory optimum moisture content, field density test should be made throughout the section. These tests should be made for at least each 93 sq.m. of test section area, and should be distributed over the area that they will detect the

effects of different compaction conditions encountered during construction. For example, if the section is located near an abutment, certain parts of the area will receive more compaction from track travel than others, hence some tests should be made in the portion compacted only by the rollers and so reported.

(vii) The next step is to compact another 3 or 4 layers at the moisture content slightly higher (1 percent or 2 percent) than the moisture content previously used, maintaining the same rolled thickness of layer and number of roller passes as in above. Field density tests are again made over the test section.

(viii) If the resulting field dry densities (of materials passing the No. 4 sieve) from (vii) above shows an increase, with increase of moisture, again by another 1 percent or 2 percent, repeat the test. If an increase in moisture results in a decrease in field density, then place the next layers slightly dry of the original moisture content used and repeat the test. This procedure is nothing more than developing on the embankment a moisture density relation or compaction curve for a certain roller, thickness of layer, and a given number of roller trips. If special studies during investigation have indicated that, the material being tested should be placed within certain moisture limits, or if the moisture limits to be used have been specified, the procedure outline above should include tests at these moisture contents or at moisture contents both greater and smaller than the specified.

(ix) The roller compaction curve is now compared with the standard laboratory compaction curve. If the field density of materials passing the No. 4 sieve (from the roller curve) is greater than the standard compaction density at the specified moisture content, the test section should be continued decreasing the number of roller trips while maintaining the specific desirable moisture content until the most economical compactive effort is determined. When the roller trips are decreased, the required spread thickness of layer that will compact to the specified thickness of compacted material should be reckoned.

(x) All works connected with the embankment test section will be done departmentally and shall be allowed without hindrance.

4.16. TURFING -

After the slope has been dressed to line, it shall be slightly roughened to bond and hold a surface dressing consisting of a 150 mm layer of good soil. The layer shall then be raked and lightly rolled with hand roller or hand tamped as directed by the Engineer - in - charge the entire slope surface shall then be covered with a layer of turf sod. The sod shall include a mat of roots and earth at least 50 mm thick. Sod containing an excessive amount of obnoxious growth shall be excluded. Sods shall be carefully handled in transportation and transplanting so that a minimum amount of earth will be lost from the root mass. The strips of blocks of sod shall be laid on the slope in close contact and then tamped firmly in place so as to fill and close the joints between the blocks. The interval of time between cutting and laying shall be kept to a practicable minimum and sod shall not be permitted to dry out. Immediately after placing, the sodded slope shall be thoroughly wetted and kept moist for 10 days. The sodded slope shall be periodically moistened, if necessary for a sufficient period to re- establish the plant growth. Humus sod shall be transplanted only during an approved season. Alternatively the down stream slopes shall be topped with a 150 mm layer of good top soil and seeded with approved grass seed as directed.

4.17. ADDITIONAL SPECIFICATION FOR CANAL EARTH WORK:

4.17.1 Alignment and Layout of Canals:

No work will be started unless alignment including curves is set out, reference lines and check profile given in accordance with para 4.3 of the specification and edges of excavation and toes of banks etc., are dog - belled or otherwise suitably demarcated as directed by the Engineer - in - charge.

4.17.2 Canal in Cutting - General -

(i) Excavation shall be carried out according to design with accurately graded bed fall and sides properly sloped in accordance with drawings.

(ii) The excavation shall be done by first cutting a central trench with slopes having steps with 30 cm. rise and tread in accordance with the prescribed side slopes. When excavation is so completed upto bed level, sides will be finally trimmed to correct profile by knocking off the steps and dressing the slopes to as smooth a surface as the nature of soil permits. In cutting in hard rock smooth side cannot be obtained and it

must suffice that the canal is excavated to the full section and depth. Trimming of slopes shall not be started unless excavation is completed to correct bed level in full width designed, and the work executed is accurately checked with respect to the reference line by the Engineer - in - charge. Finishing of slopes should be done neatly and free from bulges, dents and wavy and undulating surfaces. To obviate such defects, trimming of slopes in small lengths less than 60 m. should be avoided.

(iii) The classification of soils will be on the basis of classification visible at both the sides of the excavation, but ridges (addies) or deadmen (matamas) may be left at suitable intervals, if so directed by the Engineer - in charge for facility of classification of soils.

(iv) Excavated materials will be utilised in accordance with typical sections of canal given in the drawings, either (a) In forming the canal banks on either side or (b) In embankments in other filling reaches of the canal or (c) In spoil banks or (d) in any other suitable places as may be directed by the Engineer - in - charge in case of excavation in rock excavated stuff will be neatly stacked as directed by the Engineer-in-Charge and in such way that these can be easily removed or transported for other works. If so directed by the Engineer -in -charge the materials will be stacked separately according to their gradation like masonry stones, rubble, pitching stones, boulders chips etc.

4.17.3 Canals in Full Cutting:

(i) Excavated earth will be uniformly deposited in the canal banks or in the spoil banks so that the banks have a neat appearance.

(ii) In the case of canal service bank, which has to carry the service road for inspection earth should be deposited in uniform layers not exceeding 20 cm. Clods exceeding 10 cm in size will not be allowed without breaking them to proper size.

(iii) In non - service bank and spoil banks thickness of layer should not exceed 30 cm.

(iv) In case of all banks (Including spoil), more gravelly material will be deposited as far as possible on the top and in slopes and top of banks with slope as indicated in the typical sections.

(v) In ridge canals continuous stretch of spoil banks shall be broken by leaving a gap of 3 m or more at suitable intervals of 150 metres or as directed by the Engineer - in - charge to allow for drainage or passage of traffic etc. However, In case of contour canals such gaps will not be left in the upstream spoil bank so that drainage water from the sidelong ground does not enter the canal.

4.17.4. Canal in Partial Cutting:

(i) Relevant stipulations of the sub- paras 4.17.2. (i) and 4.17.2. (ii) above shall apply to this case also. Banks will be formed in uniform layers not exceeding 20 cm thickness or as may be directed by the Engineer - in - charge and no clods exceeding 10 cm will be allowed. Clods exceeding 10 cm size should be broken to proper size. In case, the embankment is more than 3 metre height, work of watering moisture control & compaction shall be done as per stipulations in Para 4.5., 4.8., 4.9. and 4.15..

(ii) Where the banks have to retain water, they shall be formed, if so directed, with core of impervious materials, firstly from the cutting of the canal and failing which from other borrow areas. Core will be covered with suitable semi - pervious or pervious material that may be available.

(iii) Before commencing of embankment the seat will be cleared and stripped and ploughed and furrowed or benched if so directed in accordance with para 4.17.7.

4.17.5. Canals in full Embankment not exceeding 3 m from Base to the Top - All relevant stipulations of paras 4.17.2. to 4.17.4. above will apply in this case also. Embankment shall be made in stretches not less than 100 m,

4.17.6. Canal in full Embankment exceeding 3 m height from Base to the Top - In this case construction of embankments shall follow, unless repugnant to the context, all the relevant specification for construction of an earth dam for a reservoir stipulated in paras 4.5, 4.8 to 4.16 and 4.17.7 subject to the modification stipulated in para 4.17.8 below.

4.17.7 Striping, Benching and furrowing and Ploughing:

4.17.7.1. The ground surface under all canal embankments excepting rock surface, where it is below full supply level in the canal be stripped, benched or furrowed and ploughed as per guidelines given below if not specified otherwise.

4.17.7.1.1. Benching - Benching should be provided only where the work is to be done on highly undulating stiff ground, steeply sloping ground or on existing canal embankments. Benching shall consist of excavation of triangular trenches with a slope of 1 In 12 with average depth of cutting as 15 cms, longitudinally below the embankment seat or in the form of steps with height of steps not more than 30 cms. The slope of trenches shall be towards the centre from the outer toes of the embankments.

4.17.7.1.2. Striping and Ploughing and Furrowing - Recommended treatment on embankment seat for stripping and ploughing and furrowing under different situation should be as below:

S.No.	Type of vegetable growth on	Depth of stripping for				
		Q < 3.0 cumecs		Q > 3.0 cumecs		
		H > 1.5 m	H < 0.6 m	H > 0.6 m	H < 0.6 m	H > 3.0 m
1.	Soil Containing grass cover	8 cm.	Nil only ploughing and furrowing	15 cm.	Nil only ploughing and furrowing	15 cm.
2.	Agricultural land	Upto depth of ploughing but not exceeding 15 cms	----do----	15 cm.	----do----	Upto depth of ploughing but not exceeding 15 cms

- Note :**
- Where FSL in the channel is below the ground level, neither stripping, nor ploughing and furrowing shall be done.
 - None of the treatments described in the above table shall be done for seat under spoil banks.
 - Where the depth of stripping needed is more than 15 cms, it shall be carried out only after approval by the Engineer - in - charge.

The foundation for canal embankments shall be prepared in accordance with para 4.9.2 (a) to (c) depending upon the nature of foundation materials.

4.17.7.2. Disposal of materials - In all the items of benching / stripping and preparation of base on rocky strata, described in para 4.17.7.1. above, the material from excavation, shall be deposited in specified areas in a manner as may be directed by the Engineer - in - charge and in such a way as not detract from the finished appearance of the work.

4.17.8 Compaction - The dry density shall not be less than 90% of M. D. D. in case of unlined canal more than 3 m height of embankment and lined canal irrespective of the height of embankment. Work of watering, moisture control and compaction shall be done by the contractor, wherever it is so specified.

4.18 TRANSVERSE CONTRACTION JOINT IN DAM / BARRAGE:

4.18.1. General - Vertical transverse contraction joints shall be provided in the masonry and / or concrete of the dam/barrage for convenience in construction and to provide for contraction of masonry/ concrete. The location and details of these joint shall be as shown on the drawings. The joint shall extend through the full cross section of the dam profile and shall be started from the foundation. The contraction joint in the concrete portion shall be smooth, as obtained with plane surfaces of form works in the case of masonry,

the edge of the block at the joint shall be built with selected stones and the surface plastered with cement mortar appropriate to the zone. The finish of end block of each contraction joint shall be such that an average thickness of 40 mm plaster gives smooth plumb surface.

The joint shall be sealed at the upstream face by installing water stops as described in para 4.18.2

4.18.2 Waterstops across Transverse Contraction Joint:

4.18.2.1. Materials:

(A) Metal Waterstop - The waterstop shall be made out of 1.5 mm thick strips of copper or stainless steel as specified on the drawing conforming to IS: 1972 - 1977 and IS: 6911 - 1972 respectively.

Subject to the provisions on the drawings, the waterstop shall have either of the two shapes viz. 'Z' and 'M' shapes shown in Fig. A of PLATE: 1/ CH-4*.

(B) Rubber/ PVC waterstop - The rubber Water stop shall be fabricated from natural rubber and shall meet the test requirement given in relevant parts of IS: 3660.

The PVC Waterstop shall be fabricated from a plastic compound, the basic resin of which shall be polyvinyl chloride and shall meet the test requirements given in relevant parts of IS: 8543

The Rubber / PVC Waterstop shall meet the requirements given in Table 2.

Table 2 : Performance Requirements of Rubber / PVC Waterstops.

SL. No.	Characteristics	Unit	Value
i)	Tensile strength	N/mm ²	11.6 minm.
ii)	Ultimate elongation	%	300 minm.
iii)	Tear resistance.	N/mm ²	4.9 minm.
iv)	Stiffness in flexure	N/mm ²	2.48 minm.
v)	Accelerated extraction		
	(a) Tensile strength	N/mm ²	10.5 minm.
	(b) Ultimate elongation	%	250 minm.
vi)	Effect of alkali (7 days).		
	(a) Weight increase.	%	0.25 maxm.
	(b) Weight decrease.	%	0.10 maxm.
	(c) Hardness change	Point	± 5
vii)	Effect of alkali (28 days).		
	(a) Weight increase.	%	0.40 maxm.
	(b) Weight decrease.	%	0.30 maxm.
	(c) Dimension change	%	± 1

Unless specified otherwise the shape and dimensions of Rubber/ PVC shall be as given in Fig B of PLATE: 1/CH-4*.

(C) Asphalt Waterstop - Recommended specifications of asphalt are given below: -

(a)	Density	...	1015-1065 Kg/m ³
(b)	Penetration at 25° C	200-300
(c)	Softening point (Ring and ball test)	80-90° C

- (d) Brittleness test on 22 mm² specification
 at 5° C energy absorbed. 0.97 Kg/m

The location, shape and dimensions of asphalt waterstop shall be as given in Fig. C of PLATE: 1/CH-4*

***For figures see specifications published by E- in - C.**

4.18.2.2. Installation of Waterstops :

4.18.2.2.1. The joints shall be sealed at the upstream face by installing. One line of metal waterstop and one line of Rubber / PVC Waterstop separated with one line of Asphalt water seal in between, as per general arrangement shown in Fig. C of PLATE: 1/CH - 4.* In addition one line of Rubber / PVC water stop across the joint around galleries/adits shall be provided as shown in Fig A of PLATE: 2/CH-4.*

4.18.2.2.2. The metal waterstops shall be erected in place with the help of anchor rods.

4.18.2.2.3. In the case of masonry dams, the surface adjacent to the block- outs (shown by dotted lines in Fig. C of PLATE: 1/CH-4.)* shall be irregular and the joints in the masonry shall be raked out when mortar is green, with some stones protruding beyond the dotted lines regularly in both directions. No such block - outs shall be provided in concrete dams where concreting on either side of the water seal is done along with the concreting of the rest of concreting block.

4.18.2.2.4. An asphalt waterstop, where specified, shall be constructed by forming a well of square opening with 125 mm side across the contraction joints. In this asphalt well, two 12 mm dia steam heating pipes (standard black welded steel) for reliquifying asphalt shall be installed. These pipes will be rigidly clamped in place and will be provided with threads and caps. The asphalt shall be poured in lifts corresponding to the concrete lift. The steam shall be passed through steam heating pipes after seal is completed upto top. It shall then be capped as in the drawing (Fig. B of PLATE: 2/ CH -4 AND Fig OF PLATE: 3 /CH-4)*

4.18.2.2.5. 25 mm dia dowel bars 1500 mm long (500 mm in concrete and 1000 mm in masonry) at the rate of 500 mm. centre to centre in both directions shall be provided at the concrete/ masonry interface of the block- out in case of masonry dam to prevent shrinkage cracks at the interface.

4.18.2.2.6 Adequate provision shall be made to support and protect the waterstops in position during the progress of work and adequate care taken while removing forms so that the bond between the seal and masonry of concrete is not broken. To provide good mechanical bond 10 mm dia M.S. bars of 500 mm length shall be brazed at one end to the sealing strip at 1 m vertical interval. The other end of this bar shall be hooked and tied around 20 mm dia bars embedded vertically in the block-out concrete.

4.182.2.7. The block- out shall be concreted in lifts not more than 1.5 m. Minimum grade of concrete used in block -out of one shall be concreted first and the joint face given a coat of coaltar black paint conforming to IS: 290 - 1961 and then only the block-out of the second block shall be concreted so as to have a clear contraction joint.

4.18.2.2.8. The concrete surrounding the waterstops shall closely follow the masonry in the block and at no time shall the top of concrete be lower than the general elevation of the masonry in the lower of the two adjacent blocks by more than 1.5 m.

4.18.2.2.9. Unless otherwise shown on the drawing, the details of waterstop arrangement (at contraction joint between two monoliths of a dam) near the top of a non-overflow section shall be as shown in Fig. B of PLATE : 2 /CH-4* and that near the crest of an overflow section as shown in Fig. of PLATE : 3/ CH-4* and near the bottom of the dam in Fig. of PLATE : 4/ CH-4*.

4.18.2.2.10. If not shown otherwise on the drawing Rubber/ PVC Waterstops shall be provided around galleries/adits at the contraction joint between two monoliths of a dam as shown in Fig A of PLATE 2/CH 4*.

4.18.2.3. Jointing:

4.18.2.3.1. Rubber/PVC Waterstops shall be jointed in straight reaches only. The waterstops shall be jointed carefully by heat sealing.

***For figures see specifications published by E- in - C .**

4.18.2.3.2. Jointing In Copper /Stainless Water seals shall be by careful brazing/ welding respectively so as to form a continuous watertight diaphragm.

4.19 DIAPHRAGM WALL:**4.19.1 Materials:**

4.19.1.1. Cement - The cement shall be ordinary Portland cement conforming to IS : 269 - 1989 and blast furnace slag cement conforming to IS : 455 -1976 or pozzolana cement conforming to IS : 1489 - 1976. Other specifications for storage, testing etc., shall be as described under relevant paras of Chapter - 7 & 16.

4.19.1.2. Aggregate- All the aggregate (coarse and fine) shall conform to the specification laid down under relevant paras of Chapter 7&16. Unless specified otherwise well graded coarse aggregate of 20 mm size shall be used in reinforced cement concrete diaphragm wall . For plain concrete, plastic concrete or grout cut wall, (Sand, Bitumen, Cement mix) a smaller size of aggregate may be used.

4.19.1.3. Water- Clean water free from deleterious impurities as per specification laid down under relevant paras of Chapter - 7 & 16 shall be used in concrete mixing. Water used for bentonite slurry shall be free from salinity and other deleterious impurities.

4.19.1.4. Admixtures - If required chemical admixtures in concrete shall be used as specified in IS: 456 - 1978.

4.19.1.5. Reinforcement - Mild steel and high tensile steel bars and hard drawn steel confirming to IS: 432 (Pt-1) - 1982, Cold twisted bars conforming to IS: 1786-1985 and hard drawn steel wire & fabric conforming to IS: 1566 –1982 shall be used and structural steel sections conforming to IS: 226-1975 shall be used.

4.19.1.6. Concrete- Concrete shall conform to detailed specifications laid down under relevant paras of Chapter 7 & 16 and Para 4.19.7.3. of this chapter.

4.19.1.7. Bentonite - Sodium based bentonite shall be used in preparing bentonite slurry. The concentration of bentonite slurry used shall confirm to requirements discussed under para 4.19.3. for sodium and chemically contaminated ground water condition. The slurry may be suitably processed with chemicals .

4.19.1.8. Grouts- In case of grouts walls, the cement, clay and chemical grouts used shall be designed and tested according to requirement of the structure.

4.19.1.9. Retarding Agents - Retarding agents and expansive additives may be added in the cement clay grout if required.

4.19.2. Equipment and Accessories:

4.19.2.1. Trenching Equipment - Depending upon the type of soil encountered soil encountered at the site and the depth, length and thickness of diaphragm wall to be constructed, suitable

trenching equipment shall be chosen. The general trenching equipment shall include rotary boring rigs, percussion boring rigs, trenching bucket type shovels, mechanical grabs, hydraulic grabs with kelly bars, grabs controlled by suspended wire ropes of a crane winch, direct mud circulation boring rigs, reverse circulation rigs and submersible motor drills for trenching equipments. For gravelly soils, boulder deposits specially designed chiseling equipments shall be considered. When required methods using combination of above processes may be chosen.

4.19.2.2. Bentonite Slurry, Preparation and Testing Equipments - Tanks of suitable sizes and slurry pumps of suitable capacity should be used for storage, mixing & circulation of bentonite for slurry at site. A separate water pump may be used for water supply to slurry tank. Equipment for sampling the slurry from deep trenches and testing its concentration, viscosity, PH value and hardness of ground water in which the bentonite slurry and concrete are prepared, should also be used. The tasting of slurry after contamination with soil or cement indicates the need of disposal or reuse as the case may be. Vibrating screens hydrocyclones, and centrifuges for cleaning the bentonite slurry for reuse may be employed.

4.19.2.3. Concreting Equipment - Concrete mixers, tremie pipes of suitable length and size and concrete pouring devices (manual or mechanical) shall be used according to the need of the work. The lifting arrangement for tremie pipes shall be capable of doing the works with desired speed.

4.19.2.4. Lifting Devices - Cranes of suitable capacity and boom length should be used in the case of precast wall panels for lowering them in the trenches. The same may be used for stacking the panels at site during casting the panels in the casting shed. The reinforcement cages of large depths and length of wall panels may be lifted by crane, derrick or any other suitable auxiliary rig. If the loads of the panel and reinforcement cage are small, this work may also be done by winch and pulley arrangement provided on the diaphragm-wall rig. Cranes or rigs with winches of adequate capacity may be used for operating the trenching grabs as necessary.

4.19.2.5. General Guide lines- Choice of rotary, percussion, grabbing equipment and equipment for direct or reverse circulation etc. , shall be made to suit the soil conditions . Vibrations and noise produced during construction should not have any damaging effect on the people and existing structures. Consideration shall be given in selection of equipment when they are required to work on a site with restricted space or headroom.

4.19.3 Specification of Bentonite Slurry:

4.19.3.1. Bentonite powder used for preparation of slurry will be tested for its liquid limit and the liquid limit shall not be less than 300 percent. This is normally prepared using 7% to 16% by weight of bentonite powder in water.

4.19.3.2. Following tests are normally carried out on freshly prepared bentonite slurry to be used in diaphragm walling:

Type of Test	Method of Test	Permissible value at 200 C
Density	Mud balance or hydrometer	1.04 to 1.10 g/ml.
PH Value	PH indicator paper Strips	9.5 to 12
Viscosity	Marsh cone method	30 to 90 seconds
10 minute gel Strength	Shearometer or vane Shear apparatus	1.4 to 10 N/m ² (14 to 100 dya / cm ²)

4.19.3.3. The relationship between concentration "C" of bentonite slurry expressed as percentage by mass and the density Ys is give below.

$$Y_s = 1.0 + 0.006 C.$$

Note: - The above relation is valid for Indian bentonites and represents an average sample. There may be some variations of bentonites. Laboratory calibration may be prepared for the bentonite samples actually used.

4.19.3.4. Tests to determine density, viscosity, shear strength and PH value shall be carried out until a consistent working pattern is established, taking into account the mixing process, blending of freshly mixed bentonite slurry with previously used bentonite slurry.

4.19.3.5. When results show consistent behavior, the test for shear strength and PH value may be discontinued and only tests required to determine density and viscosity need be carried out.

4.19.3.6. The frequency of testing shall be on panel to panel basis where bentonite slurry becomes heavily contaminated with fine sand during its first use, and may be on a daily basis where contamination may be slight. In cases where a mechanical process is employed to remove contaminating solids from the slurry the frequency of slurry testing shall depend on equipment employed.

4.19.3.7. Prior to placing of concrete in any panel a bentonite slurry sample shall be taken (that is about 0.2 m from the trench bottom) and the same shall be tested for density. The sampling shall be done carefully by an appropriate method. The density thus determined shall not be greater than 1.25 g/ml to ensure satisfactory placing of concrete. If the slurry is found to have higher density the same shall be thinned by feeding in fresh bentonite slurry till the required density is achieved.

4.19.3.8. Suitable slurry pumps, submersible pumps or airlift shall be used in replacing the contaminated slurry at the bottom of trench by fresh bentonite slurry.

4.19.4. Bentonite Slurry and Additives:

4.19.4.1. Sodium based bentonite powder shall be mixed thoroughly with potable water to form a fully dispersed lump- free homogeneous slurry. Suitable slurry taken shall be used for this operation. The use of a slurry pump with special nozzle (Fig. A of PLATE: 5/CH - 4)*. is suggested for preparing bentonite slurry. Use of paddle stirres or other mechanical devices such as colloidal grout mixer (Fig. B of PLATE: 5/CH-4) *, may also be made for proper mixing of slurry, the temperature of water used and of the slurry used shall not be less than 5⁰ C.

For proper stabilisation of the trench walls by bentonite slurry, it is essential to allow adequate gelation period for bentonite slurry. For this purpose the slurry should not be used for a period of minimum 12 hours after it is mixed thoroughly.

4.19.4.2 Where saline or chemically contaminated ground water is present, special additives listed below may be used to render bentonite slurry fit for use. These additives are used in very small amount of 0.1 to 0.5 percent by mass of the slurry.

(i) Ferrochrome lignosulphonate in combination with soda ash or bichromate of soda may be used for effective bentonite hydration, If hardness of water exceeds 200 PP.

(ii) Sodium Carboxymethyl Cellulose (S. C. M. C.) is yet another additive some times used. It protects slurry against effects of electrolytes, accelerates filter cake formation, and reduces fluid loss by increasing the viscosity of slurry.

(iii) Cement contamination may be counteracted by phosphates. The Calcium gets removed and clay solids dispersed. Phosphates decrease PH value thereby lowering viscosity and yield value of slurry.

(iv) Carboxymethyl Cellulose, gums or pre-sheared asbestos may be used, to increase Viscosity and reduce filter loss.

(v) To remove fine silty solids and clay solids from the slurry, flocculants may be used. Vinyl Acetate maleic anhydride co- polymer or polyacrylamides may be used. Gaur gum can flocculate clays, carbonates, etc.

(vi) Pregelatinised starch may be employed as a fluid loss control. It may also be used as a protective colloid against the effect of electrolytes.

(vii) Stability of slurry filled trenches should be worked out as per procedure described under Appendix - II.

***For figures see specifications published by E- in - C.**

4.19.5. Guide Wall / Pre-Trench:

4.19.5.1. RCC guide wall / per- trench shall be constructed prior to main slurry trenching operation.

4.19.5.2. Guide walls shall be 100 to 250 mm thick, 1 to 2 metre deep and made of lightly reinforced concrete (not inferior than M 10) and shall represent the reference lines. In soft ground or fill, guide walls may be taken deeper. When ground water is close to the surface, guide walls higher than the surface level shall be constructed to maintain slurry head. The top of per trench level will be minimum 1.5 m above the high water table.

4.19.5.3. The clearance between finished diaphragm wall & guide wall shall be 50 mm minimum for straight panels. The clearance shall be suitably increased when the panels are curved. The finished faces of the guide walls towards the trench shall be vertical. Guide walls after construction shall be suitably propped where necessary to maintain specified tolerance. Mesh or cage reinforcement shall be used in guide walls.

4.19.5.3.1 For heavy machinery, guide walls shall be constructed with suitable ground slab (on both sides of the wall).

4.19.5.4. Guide walls get support from adjoining panels and therefore, their construction shall be done continuously.

4.19.5.5. The trench shall be kept filled with bentonite slurry before the commencement of boring / grabbing operation for any diaphragm panel. The level of bentonite slurry in the trench shall be minimum 1.0 m above the ground water table . When the boring operation is in progress, the level of bentonite slurry will be maintained by addition of bentonite slurry.

4.19.6 Methods of Construction:

4.19.6.1. General - Cast - in - situ structural R. C. C. diaphragm wall shall be constructed by resorting to either successive panel method or alternate panel method. In successive panel method, a panel shall be cast by the side of another completed panel, so as to form a good joint and a continuous leak proof diaphragm wall. In alternate panel method, primary panels shall be cast first, leaving suitable gaps in between. Secondary panel shall then be cast, resulting in a continuous diaphragm wall. The panel lengths vary depending on the soil strata and depth of trenching and surcharging however lengths of 1.5 m to 6 m are usually adopted. .

4.19.6.2. Successive Panels Method - In this method a panel shall be cast in continuation of previously completed panel. Use of form tubes is generally a joint between primary panels and secondary panels. However, with longer width of diaphragm wall and greater depth of diaphragm wall it may not be possible to provide form tube due to handling, lowering and extraction difficulties. In such a case, special tools such as semi circular chisels are used to effect a joint between primary and secondary panel and in this case form tubes are eliminated. Form tubes of 1 m dia and 30 m length have been used successfully (Fig. of PLATE : 6/CH - 4)*.

4.19.6.3. Alternate Panel Method:

4.19.6.3.1. In this method primary panels shall be cast first leaving suitable gaps in between. Secondary panels shall then be cast in these gaps (Fig. of PLATE: 7/CH-4)*. Two stop end tubes are used at the ends of primary panels to support concrete and form suitable joints with the secondary panels.

***For figures see specifications published by E- in - C.**

4.19.6.3.2. The excavated length of secondary panels may be smaller than that of primary panels.

4.19.6.3.3. The shape of the secondary panel end should be such as to form a good joint with primary panels.

4.19.6.3.4. Other construction techniques are same for successive and alternate panel method, which are described below.

4.19.7 Stages of Construction:**4.19.7.1 Excavation of Trench (Boring Operation):**

4.19.7.1.1 General - Excavation of each trench panel (Fig of PLATE: 6/CH-4)* shall be done with the help of suitable machinery. The trench panel shall be kept filled with bentonite slurry of suitable consistency & viscosity during the excavation period. Before commencement of boring, length of the panels will be properly demarcated on the pre-trench wall. Panel boring can be done either by direct circulation or reverse circulation method described below.

4.19.7.1.2 Direct Circulation Method:

(i) This method is used with rotary or percussion type rigs where drilling fluid (bentonite slurry) is pumped through the drilled rods. It can be used for successive panel or alternate panel construction. The stages of construction are shown in fig of PLATE: 8/CH-4*. Simple trenching rigs for excavation may be used. Special cutters (for cutting and jointing) and elliptical or circular concreting tremie pipes for backfilling the trench panel may be used.

(ii) The trench panel may be excavated in the ground by making over lapping boreholes with bentonite slurry jet in combination with percussion and to and from rotary motion of jetting pipe having a suitable cutter at the tip.

(iii) A special semi-circular cutter shall be used for providing appropriate shape at each panel end to form a suitable joint.

(iv) The operation of filling bentonite slurry in the trench shall be as described under para 4.19.7.2.

(V) For Thicker walls that is 40 cm and more, suitable modified semi-circular jointing cutter may be used.

(vi) This method is suitable for shallow depths and bringing up lighter cuttings.

4.19.7.1.3. Reverse Circulation Method:

(i) The reverse circulation method with in percussion shall be used to make trench panel in the ground as shown in Fig.A of PLATE: 9/CH-4*. Forward and backward movement of the rig from one end of the panel to the other end shall increase the depth of panel in a zigzag manner.

(ii) High capacity pumps shall be used to suck the loosened soil in the slurry filled trench, Separators or sedimentation tanks shall be used to retain the soil cuttings, and to pass the slurry for circulation and reuse.

(iii) This method is suitable for greater depths and to bring up heavier cuttings.

4.19.7.1.4. Other requirements during Boring operation:

(i) Solids in the setting tank shall be removed and kept along side. When the grabs or kelly method is used for boring, bored muck from the grab will be left along side.

(ii) For overcoming any under obstruction or boring through all types of rocks such as soft rock, weathered rock, disintegrated, rock, hard rock, boulder etc. the use of chisel grab will be made in case of grab type equipment. In case of reverse circulation equipment the cutting tool itself will execute chiseling operation in above-mentioned strata.

(iii) The width of cutting tool will be more or less as that of the diaphragm wall. The trench shall be finished upto founding level in the final stage of preparation by using a cutting tool having a width of not less than 600 mm before commencing placement of concrete.

(iv) Boring shall be continued in the manners described above upto founding level. Depth of the trench will be determined by taking sounding. Diaphragm wall shall penetrate about 0.6 meter into sound rock, which shall be ensured by careful soundings taken and certified by Engineer - in - charge. If there is difference of more than one metre or more in the rock level at two ends of the panel, suitable stepping as decided by Engineer - in - charge shall be provided.

(v) Before removing the equipment, the bottom of the trench will be cleaned by reverse circulation equipment.

(vi) Form tubes will be lowered at each end of primary panels in case of construction by alternate panel method and reinforcement cage shall then be lowered in the trench panel and suitably supported.

4.19.7.2. Reinforcement:

4.19.7.2.1. Method of Preparation - Method of preparation of reinforcement cage is as under: -

(i) Reinforcement in each panel should form a cage and the vertical ends of the cage should match with the type of joints of the panel. For ease of handling and good workmanship the cage should be made rigid. Clear distance between reinforcement bars should not be less than 100 mm for easy flow of concrete.

(ii) The length of the cage will be governed mostly by the depth of panel, and the length of rods available. The cage shall however, be built up preferably in two fabricated matching pieces but in no case in more than three pieces. Each subsequent reinforcement cage after the first cage shall be securely fastened and tack welded to the lower cage before the assembly is lowered to the trench. The steel reinforcement cages shall be clearly marked to indicate its correct orientation for proper insertion into the trench.

(iii) The gap in the main bars should not be staggered more than 50 cms to avoid difficulties in handling the cage and dropping the cage.

(iv) Suitable gaps in the reinforcement cage will be provided for accommodating the tremie required during concreting operation.

(v) The reinforcement cage will be suitably strengthened at regular intervals and generally the bars will be tack welded.

(vi) In case the reinforcement cage is heavy, angle iron frames may be utilised.

(vii) The concrete cover for reinforcement shall be maintained by the use of spacers. Circular roller cement concrete cover blocks using 1.1.1/2:3 cement concrete mix shall be provided at suitable intervals preferably one block per square meter on both sides of the cage and suitably staggered. The diameter of spacer block will depend upon clear cover required for the reinforcement.

Boxes are inserts for formation of recesses or for ground anchors shall be lowered along with the cage to correct position and levels. Circular cover blocks are considered essential to the reinforcement so that they will roll along the trench without damage and maintain adequate cover.

(viii) The hooks for lifting the reinforcement cage will preferably be of Mild steel, and diameter and number should be adequate to withstand the weight of the cage.

(ix) The reinforcement cage should be kept hanging over pretrench to provide a minimum cover of 10 mm at the bottom of trench and it shall be maintained in position during the concreting of each panel.

(x) Rock grout pipes shall be fixed with suitable spacer bars at specified intervals.

4.19.7.2.2. Jointing and splicing - Joints and splices in reinforcement shall be provided at positions shown on the approved drawing. This shall be done as per detailed specification laid down under para 13.3.5. of Chapter 13 specifications for "Steel and iron work" The joints between main reinforcement bars, the links and other steel sections shall be properly welded with respect to design considerations and handling requirements. Welding shall be done according to relevant Indian Standard while using mild steel bars in concrete construction.

4.19.7.2.3. Reinforcement for Walls other than Structural Member - In case the diaphragm wall has not been designed as a structural member nominal reinforcement as per IS. 456 . 1978 shall be provided.

The usual provision is 16 mm dia to 20 mm dia bars at 300 mm to 325 mm centre to centre in both direction with a cover of 75 to 100 mm at faces and at ends of elements.

4.19.7.3. Concreting:

4.19.7.3.1. Concrete for the RCC diaphragm wall shall be composed of cement, sand, coarse aggregate, water and any other admixture as decided, all well mixed and brought to the consistency, Random samples from fresh concrete shall be taken as specified in IS : 1199-1959 and cubes shall be made, cured and tested as described in IS 516 - 1959 . If required the mix should be modified to achieve the desired strength, workability, density and impermeability with maximum permissible economy. Concrete will be designated M -20, which means that 28 days cube strength will be 20 N/mm² or 200 Kg/ cm². The water cement ratio for concrete shall be governed by the requirement of strength, durability and workability, but it shall not be greater than 0.6.

The concrete shall be of uniform consistency and quality throughout any pour and for similar parts of the same structure. However, consistency and composition shall be such that the concrete can be worked out in all corners and angles of the forms (for cap work) and that concrete surrounds completely the reinforcement and embedded metal without causing segregation of the ingredients.

4.19.7.3.2 The control of concrete is based among other factors on maintaining a fairly uniform slump at the point of placement and holding the water cement ratio as closely as practicable to 0.6.

4.19.7.3.3. The slump should be measured in accordance with the method prescribed in IS: 1199-1959. The slump of concrete should be 150 mm to 200 mm for ensuring easy flow through for tremie pipe used in concreting.

4.19.7.3.4. The concrete mix shall be suitably designed for the required slump and ten percent extra cement added for under water work for laying concrete by other than tremie.

4.19.7.3.5. Concrete Classification:

4.19.7.3.6. Concrete classification is related to the specified 28 days compressive cube strengths and shall conform with the requirements set out in table below.

SI No.	Location	Classification	Slump
1	Concrete in R.C.C. Diaphragm walls	M. 20	150 to 200 mm
2	Concrete in R. C. C. Capping.	M 20	50 to 75 mm

Exact mix design however, shall be determined by laboratory tests.

4.19.7.3.7. A minimum of 3 tests specimens shall be made for each 120 cum. of each class of concrete. There shall be atleast 3 test specimens for one day of concreting even if only a few cubic metres of the particular concrete is manufactured in a day. Additional tests shall be carried out as and when directed.

4.19.7.3.8. The tests shall satisfy the criteria as prescribed under para 7.2 of Chapter 7 & 16.

4.19.7.3.9. Concrete materials, production of aggregate, batching, mixing, transporting and preparation for placing of concrete shall be done in accordance with the relevant paras of Chapter 7 & 16.

4.19.7.3.10 Placing and Compacting for Diaphragm Wall:

(i) The concreting shall be done by tremie pipes and the tremie diameter will be minimum 200 mm. It is preferable to use threaded tremie pipes in suitable lengths. The tremie pipes shall be clean & water tight. Depending upon the length of panels one or more tremie pipes should be used. The elliptical or oblong tremie pipe shall be used for concrete having aggregate of 20 mm and smaller. This shall be used for walls of 20 to 30 cm thickness. For walls of greater thickness a circular tremie pipe may be used.

(ii) Prior to placing concrete in any panel it should be ensured that heavily contaminated bentonite slurry has not accumulated in the bottom of trench, which can impair free flow of concrete. The contaminated bentonite slurry shall be identified by taking a sample of the slurry from near the bottom of the trench and carry out a density test on this using a mud balance. Density as measured shall not be greater than 1.25 gm/ml. Before pouring the concrete through tremie pipes, the bottom of the concreting funnel should be closed through a steel plate. The tremie should extend to the bottom of trench excavation prior to the commencement of concrete pouring and care shall be taken to ensure that bentonite slurry which may have entered the tremie is expelled from the tube during the initial charging process. After funnel is filled with concrete, the plate is removed and concrete is discharged. Thereafter concreting is done in a continuous manner upto required level. Care should be taken during placing to avoid contamination of the concrete where two or more pipes are used in the same panel. Simultaneously, care should be taken to ensure that the concrete level at each pipe is maintained.

4.19.7.3.11. For Cap Work:

(i) Before placing cap concrete extra concrete already placed during concreting of; the diaphragm walls above designed cut off level shall be removed by chiseling manually or by pneumatic tools.

In case concrete below the designed cut off level is found to be inferior or contaminated not conforming to specifications, the same should also be removed until concrete of prescribed specifications is met with. Minimum 15 cms (6 inches) should preferably be removed. The chipping shall be done in such a manner as not to loosen, crack or shatter any part of the work beyond the approved levels at or below the cut-off level. The surface shall be cleaned thoroughly of all loose fragments, dirt, laitance and any other objectionable materials & shall be sound & hard in such conditions as to ensure good bond between the old and new concrete.

(ii) After the surface has been cleaned and dampened as specified, surface construction joints shall be covered wherever practicable with a layer of mortar approximately 15 mm to 20 mm. thick. The mortar shall have the same proportions of water, air entraining agent, cement and fine aggregate as the concrete mixture to be placed upon it. The water cement ratio of the mortar in place shall not exceed that of the concrete placed upon it, and the consistency of the mortar shall be suitable for being spread uniformly and worked, thoroughly into the irregularities of the surface. Concrete shall be placed immediately upon the fresh mortar.

4.19.7.3.12 As far as it is practicable, concrete shall be placed directly in its final position and shall not be caused to flow in a manner to permit or cause segregation. Methods and equipment employed in placing concrete in forms shall be such as will not result in clusters or groups of coarse aggregate being separated from the concrete mass.

Concrete shall be compacted to the maximum density; in such manner that it is free from pockets of coarse aggregates & is in intimate contact with surfaces of forms & embedded materials. Unless otherwise permitted all concrete shall be compacted by mechanical vibrator.

Compaction of concrete shall, wherever practicable be carried out by the use of adequate immersion type vibrators to be operated at speeds of at least 6,000 revolutions per minute when immersed in the concrete. Vibrators having vibrating head less than 100 mm in diameter shall be operated at speed of atleast 7,000 revolutions per minute in the concrete. Normally formwork shall be designed to provide for the insertion and operation of mechanical vibrators in the placed concrete. Form vibrators shall be used wherever internal vibration is not possible or would be inadequate.

During placing and until curing is completed, the concrete shall be protected against the harmful effects of exposure to sunlight, wind and rain, as directed.

A tension zone, close to the wall capping is created because of rigid wall. Hence 1.5 m thick clay cover over the top of concrete diaphragm wall should be provided and compacted at OMC, to act as a plastic cap to account for any deformation without under going any cracking.

4.19.8. Types of Joints:

Joints between the successive panels may be achieved in any of the different ways shown in Fig. B of PLATE: 9/CH-4*. In case of alternate panel method two stop end tubes are used at the ends of the primary panels to form suitable joints with secondary panels.

4.19.9. Wall of Precast RCC Panels:

The trench panels shall be made in the ground using normal machines or grabs. The trench shall be kept filled up with self-setting bentonite slurry. Specially designed precast RCC panels with provision for suitable jointing shall be lowered in the trench with help of crane. The panels shall be supported in the trench by using special supports.

Inside face of panels before lowering them into the trench shall be treated with specified compound.

The self-setting bentonite slurry shall be slow setting & should develop adequate strength & impermeability.

The precast panels used in the process shall provide an aesthetically pleasing surface of wall on excavation of soil. The quality of concrete in PRECAST RCC panels should be better than that achieved by tremie concrete method.

4.19.10. Grout Cut- off Walls:

4.19.10.1. Where structural strength is not required the self-setting, bentonite slurry may be used to provide an impermeable cut - off wall.

4.19.10.2. When so specified suitably designed clay concrete, or sand bentonite cement mix may be used for diaphragm walls, which are primarily meant as impermeable cut- offs.

***For figures see specifications published by E- in - C.**

4.19.11. Tolerances:

4.19.11.1. Guide walls - The finished faces of the guide walls towards the trench shall be vertical, there shall be no ridges or abrupt changes on the face of the guide wall. Variation from a straight line or a specified profile shall not exceed 25 mm in 3 mm.

4.19.11.2. Diaphragm Wall:

4.19.11.2.1. Verticality - The face of the wall and ends of the panel to be exposed shall be vertical within a tolerance of 1:80.

4.19.11.2.2. The effective trimmed final wall levels shall normally be taken as 250 mm below the top of guide wall when concrete is cast to the top of the trench. If water table is high and if required cut off is low and water table is also at depth, small concreting can be stopped at lower level. For trimmed final wall levels below this level, the vertical tolerance in profile of concrete cast shall be between 150 - 500 mm above the specified wall levels.

4.19.11.2.3. Where recesses are formed in walls, these shall be positioned within a vertical and horizontal tolerance of 150 mm.

4.19.11.2.4. In positioning of reinforcement, longitudinal tolerance of cage head at top of the guide wall measured along the trench shall be 75 mm and vertical tolerance at cage head in relation to top of guide wall shall be 50 mm.

4.19.12. Rock Grouting under the Diaphragm:

4.19.12.1. Specification for this work shall be as per Chapter 22.

4.19.12.1.1. 50 to 75 mm diameter pipes shall be embedded in the diaphragm wall at specified intervals. These pipes will be welded to the diaphragm wall reinforcement before it is lowered into position. This is done to avoid drilling through diaphragm wall concrete and reinforcement.

4.19.12.1.2. After the panel is completed drilling in rock will be done with pneumatic equipment.

4.19.12.1.3. After drilling for a depth of 2 metres in rock, the hole will be washed with water and water tested to find the water loss in " Lugeon " value. Normally the pressure is increased in steps of 1 Kg/cm² to the maximum grout pressure allowed for the particular position. While decreasing the pressure 2 to 3 readings will also be taken. This procedure will help to observe the flow in the particular rock media (laminar or turbulent.)

4.19.12.1.4. Generally the packer assembly with opening at the bottom and normally fitted with 2 numbers of cup type leather washers, will be lowered to the desired depth in the hole and water will be pumped at the required pressure. The duration of the test at any particular packer position at a

particular pressure will be about 5 minutes. After noticing the flow in the media, the test at the particular packer position will be considered as completed.

A graph will be drawn showing the absorption of water in litres/ minute on abscissa and pressure on the ordinate scale .The Lugeon value is calculated by finding the absorption at 10 kg/cm^2 either by interpolation or extrapolation, per metre of the strata being tested for permeability.

4.19.12.1.5. In case of fine fissures neat cement grout will be used for rock grouting. However, if the fissures are bigger having a high lugeon value a stable grout consisting of cement bentonite and sodium silicate will be used. Bentonite in the mix will increase the injectability of cement in the rock fissures. Whereas sodium silicate will decrease its setting time and will avoid long travel of grout. This type of stable grout will be used only if it is found that consumption of neat cement grout is quite heavy and refusal pressures are not obtained even after continuous grouting for a long time .The type of mix will be decided only after conducting some trial eats at the site.

The pressure, which will be generally allowed for grouting will be as follows: -

1 PSI: For every foot of rock above the packer.

75 PSI: For every foot of overburden above rock

The grouting in rock will be done in suitable descending stages as directed by Engineer - in - charge. Criteria for the curtain grouting shall be as stated in para 3.6 & 3.6.1 of IS: 6066 -1971. **"Grouting of Rock Foundation in River Valley Projects".**

4.19.12.2. Grouting under the Diaphragm wall joints by Tube - A Manchette Method.

4.19.12.2.1. In order to prevent any leakage of water from the joints between the 2 panels of the diaphragm wall the area near the diaphragm wall joints will be grouted.

4.19.12.2.2. Boring in over- burden will be done by rotary- cum- percussion drilling equipment using the mud circulation process.

4.19.12.2.3. A manchette pipe will be lowered in the boreholes, this tube (A manchette pipe) consists of 1 - $\frac{1}{2}$ " M .S. Pipe having openings at equal intervals (4 Nos. radial perforations every 33 cms) covered by rubber sleeve which acts as a one way valve.

4.19.12.2.4. The space between the borehole sides and the Tube -A Manchette' will be filled with plastic sheath grout, which after setting will seal the tube. A manchette with the grout and will prevent upward leakage. The grout will consist of bentonite, cement and water and is so designed that it is neither too hard nor too soft .The strength of the sheath grout after setting will be such that it will be punctured when the grouting starts but it will not be soft enough to allow upward leakage along the tube 'A' Manchette pipe.

4.19.12.2.5. Generally a coarse grout of cement, bentonite mix will be grouted through the Manchette pipes in the first stage. Chemicals, such as sodium silicate and monosodium phosphate may

have to be used along with bentonite in the second stage. The first stage will be grouted at least to a pressure of 4 to 5 kg/ cm², whereas higher pressures can be allowed in the second stage grouting.

4.19.12.2.6. All necessary steps should be taken to ensure that the panel joints are grouted to required efficiency as may be prescribed by the Engineer - in- charge and also to the extent that grouting of sand between the two walls is not necessary.

4.19.13. Permeability Test For Concrete of the Diaphragm Wall:

4.19.13.1. In order to observe the permeability of the concrete in the diaphragm 50 to 75 mm diameter pipes will be provided at different levels in the diaphragm wall before concreting of the panel.

4.19.13.1.1. Drilling with appropriate size as may be decided by the Engineer - in-charge will be done through these pipes for a depth of 3 cms to 60 cms below the bottom of the pipe.

4.19.13.1.2. The test will be conducted by using " Le France's point permeability falling head method". The pressure corresponding to differential hydrostatic head when the work is completed can be applied while carrying out this test by using compressed air.

4.19.13.1.3. The computed permeability of the diaphragm concrete shall not be greater than 30 cm per year at pressure equivalent to a hydrostatic head of 40 metres.

4.19.14. Inspection of Works:

4.19.14.1 Test wells (inspection chambers) preferably of 3 m width x 2.5 m depth shall be constructed at suitable intervals as approved by the Engineer - in - charge to control workmanship quality and tolerance of the diaphragm wall. Adequate safety precautions shall be taken in construction and operation of these walls.

4.19.15. Testing Efficiency of Diaphragm Wall:

4.19.15.1 Efficiency of the diaphragm wall shall be tested by observing leakage through the diaphragm wall 'V' notches or other measuring devices shall be installed on the down stream wall and seepage measured all round the year.



APPENDIX - 1

CRITERIA FOR CONTROL OF COMPACTED DAM EMBANKMENT

Type of Material	Percentage of No. +4 fraction by dry weight of total material	Percentages based on minus No. 4 fraction					
		50 feet or less in height			Greater than 50 feet height		
		Minimum acceptable density	Desirable average density	Moisture limits $W_o - W_f$	Minimum acceptable density	Desirable average density	Moisture limits $W_o - W_f$
1	2	3	4	5	6	7	8
Cohesive Soil	0-25	D = 95	D = 98	-2 to +2	D = 98	D = 100	2 to 0 (Note 2)
	26-50	D = 92.5	D = 95		D = 95	D = 98	
Controlled by The Proctor test	More than 50 (Note 1)	D = 90	D = 93		D = 93	D = 95	
Cohesionless Soils	Fine sands with 0-25	Dd = 75	Dd = 90	Soils should Be very wet	Dd = 75	Dd = 90	Soils should Be very wet
	Medium Sands with 0-25	Dd = 70	Dd = 85		Dd = 70	Dd = 85	
Controlled by the relative density test	Coarse sands and with 0-100 gravels	Dd = 65	Dd = 80		Dd = 65	Dd = 80	

Where -

$W_o - W_f$ is the difference between optimum water content and fill water content in percent of dry weight of soil.

D is fill dry density divided by Proctor maximum dry density in percent .

Dd is relative density.

NOTES:

- 1 Cohesive soils containing more than 50 percent gravel sizes should be tested for permeability of the total material if used as a water barrier.
- 2 For high earth dams special instruction on placement moisture limits will ordinarily be prepared.

APPENDIX - II

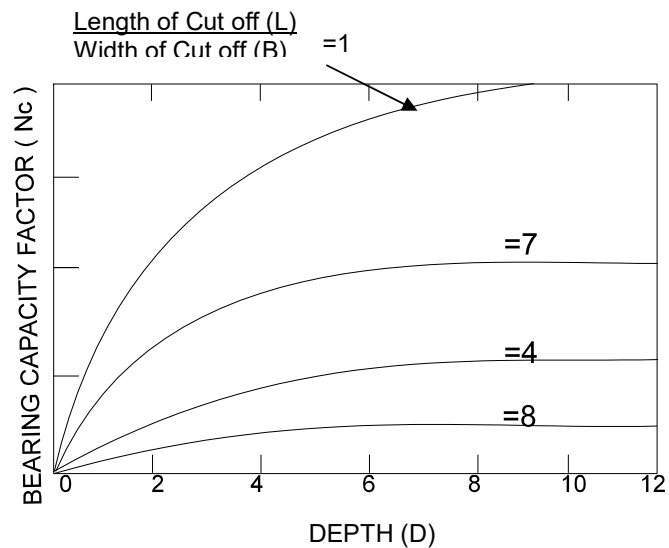
[Para 4.19 A (vi)]

STABILITY OF SLURRY FILLED TRENCHES

The bentonite slurry filled in the trench imparts stability by mainly applying hydrostatic pressure on the wall, against the impermeable thin film formed along the wall. Secondly, The slurry filled in the trench provides passive resistance against failure of the trench, and thirdly, the shearing resistance of the slurry saturated zone and the plastering effects of the filter cake formed also contribute towards trench stability. The hydrostatic pressure along represents 65 to 80 percent of the total stabilizing forces. If the density of slurry used is such that it can provide a factor of safety of one due to hydrostatic pressure, then factor of safety of the actual trench shall be between 1.25 to 1.50. Therefore, taking only hydrostatic pressure and considering $F = 1$, the density of slurry may be calculated as indicated by the following formula. This formula should be used as a guide only.

Where -

- | | | |
|----|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| H | = | depth of the trench, |
| Cu | = | undrained shear strength of clayey soil, |
| Y | = | natural density of saturated soil, |
| Ys | = | density of the slurry needed for the trench, and |
| Nc | = | bearing capacity factor which varies from 4 at the ground surface to 8 for deeper depths, depending upon D/B and L/B ratio of the trench. This factor accounts for arching action in horizontal as well as vertical directions - see figures below. |



Stability Factor N_c for Rectangular Cuts in Clay (II)

**Reduction Factor A for Earth Pressure in Trench
of Length 2b (cd = 0)**

For sandy soils

$$Y_s - Y_w + A (K_a Y)$$

Where,

$$A = \frac{1 - e^{-2n K_a \tan \phi}}{2n K_a \tan \phi}$$

$$K_a = \tan^2 (45^\circ - \phi/2)$$

$$Y = \text{effective unit weight of the sandy soil.}$$

$$= \text{Submerged weight - weight of water}$$

$$= Y_{\text{sat}} - Y_w$$

The value of A depends upon $n = \frac{\text{depth}}{\text{length}}$ ratio of the trench (see fig. above)

As a general rule, level of bentonite slurry in the trench shall be minimum 1.5m higher than the water level.